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## COMPETITION IN FUNGI

### I. A Study of the Growth Reactions of Non-Parasitic Fungi in Associated Culture

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(Communicated by Dr S N Das Gupta, Ph.D., D.I.C.)

#### *Introduction*

THE earlier works on mixed culture are mostly studies on growth reactions of fully developed mycelia in a given medium. The present work was undertaken to study the influence of one fungus upon another in paired and associated cultures in media variously modified, with a view to gaining an insight into the nature of competition in fungi.

In nature, competition occurs whenever more than one fungi associate together, and the success or failure of a fungus depends upon the chemical and physical nature of the habitat and upon the environment. It must also depend, to some extent, upon the effect the fungi exert upon one another. A study of the latter aspect is the main objective of this paper.

Growth reactions in artificial culture are not necessarily true indications of what may occur on host in nature (Machacek, 1928), but nevertheless, it was thought that studies in simpler media are likely to throw more light on general problem of competition, particularly with regard to saprophytes, than studies using complex host tissues.

This paper which is the first of a series deals with the growth reactions primarily of two non-parasitic fungi, *Fusarium* and *Dendryphiella*, in associated cultures. The detailed investigation was restricted to these two fungi only since it was found that a larger number of combinations would make the work unwieldy. Similar experiments with parasitic organisms will follow in subsequent papers of the series.

#### *Material and Method*

Six fungi were utilized for preliminary observation. The fungi differed both in the microscopic and macroscopic characters, and these afforded an

easy means of distinguishing the competing strains in mixed growths Out of these six only two fungi were chosen for a detailed investigation The names of the fungi together with a very short description of their macroscopic characters are given below

1 <i>Fusarium</i> sp	Mycelium white, moderately fluffy, non-zoning, submerged mycelium very little
2 <i>Dendryphiella</i> sp	Mycelium dark, fluffy, non-zoning, submerged mycelium abundant
3 <i>Phoma</i> sp	Mycelium white, fluffy, zoning with distinct dark-red rings Visible as light band at the top very clearly in the substratum
4 <i>Helminthosporium</i> sp	Mycelium greyish-white, slightly fluffy, zoning, submerged mycelium very little
5 <i>Monilia</i> sp	Mycelium dark-grey, moderately fluffy, zoning with rings of darker grey colour Submerged mycelium very little
6 <i>Gibberella</i> sp	Mycelium whitish-grey, mostly superficial, thin growth, non-zoning

The actual combinations in which the fungi were paired are given along with the experimental details

The method of investigation consisted in inoculating a given plate of nutritive medium with two fungi (members of a pair) and comparing the growth rates and the relative area occupied by the competing fungi with those of the controls

The strains were inoculated at different degrees of proximity, viz., 2 cm apart, adjacent (two inocula touching each other) and mixed, with individual controls

For purposes of getting the average rates of growth and also for verification of results replicates of three petri-dishes were used in each kind of inoculation with two controls for each of the strains

The growth rates of the competing fungi and of the controls were noted every twenty-four hours together with other features of interest The growths arising from mixed inocula were examined under binocular microscope whenever required

The standard synthetic medium used throughout the experiment as basal medium, except where otherwise stated, had the composition . glucose

2.0 gm, potassium nitrate 2.0 gm, magnesium sulphate 0.75 gm, potassium phosphate 1.25 gm, potato starch 10.0 gm, shredded agar 15.0 gm and distilled water 1 litre

The detailed work on *Fusarium* and *Dendryphiella* was carried out in the standard medium variously modified by the addition of N/10 hydrochloric acid and malic acid in acid series, sodium carbonate and sodium hydroxide in alkali series, in different percentages, the details of which are given in appropriate places

Petri-dishes 2 cm deep and 11 cm in diameter were used in all cases. The different media were poured 1.5 cm deep to enable to make necessary observations in the substratum as well. The usual methods of sterilizing petri-dishes and media were employed.

At the commencement of the work the purity of the various fungi was assured by taking monohyphal cultures and maintaining stock cultures in tubes of standard synthetic medium.

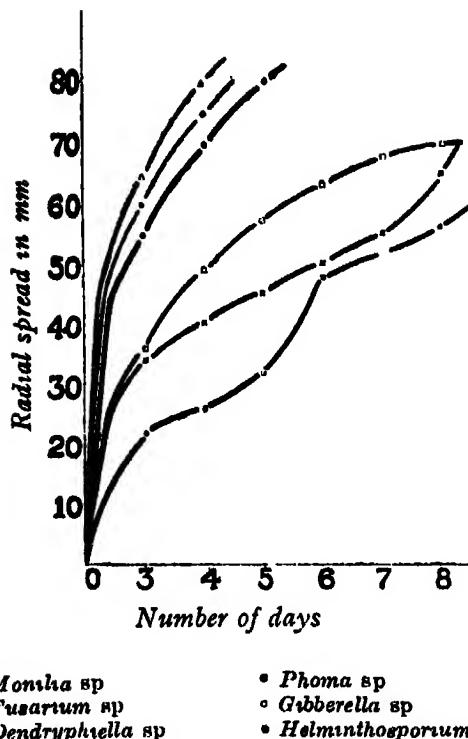
For purposes of inoculations equal amount of inocula were used from the peripheral regions of the cultures of four or five days growth in standard media and for mixed inocula cultures these were thoroughly mixed by means of a scalpel and then inoculated.

All operations were carried out in aseptic condition.

The work was done at temperatures ranging between 18–20°C.

#### *Preliminary Observations*

As has been already stated six strains were utilized for the experiment. The monohyphal cultures of all these six strains were grown in standard synthetic medium in order to compare their growth rates and their morphological characters. A short account of the macroscopical characters of each of the strains has already been given, the rate of growth for different strains is given graphically in Text-Fig 1.



TEXT-FIG 1.—Graphs showing the radial spread in mm of the fungi *Monilia* sp., *Gibberella* sp., *Helminthosporium* sp., *Fusarium* sp., *Dendryphiella* sp. and *Phoma* sp. in standard synthetic medium

It will be seen from Text-Fig 1 that *Monilia* has the fastest growth rate followed by *Gibberella*, *Helminthosporium*, *Fusarium*, *Dendryphiella* and *Phoma* in descending order

For experiment on competition the strains were paired in such a way that each member of a pair had mycelium of different colour, to enable easy detection of hyphae in mixed growth. The combinations employed were as follows :—

1. *Fusarium* .. white, non-zoning.  
and  
*Dendryphiella* .. dark, non-zoning.
2. *Fusarium* .. white, non-zoning  
and  
*Gibberella* .. greyish-white, non-zoning

3	<i>Phoma</i> and <i>Helminthosporium</i>	white, zoning
4	<i>Phoma</i> and <i>Monilia</i>	greyish-white, zoning
5	<i>Phoma</i> and <i>Dendryphiella</i>	white, zoning
		dark-grey, zoning
		dark, non-zoning

These six strains in the above five combinations were inoculated 2 cm apart, adjacent and mixed, in standard synthetic medium plates. Controls were kept.

The results show that in the combinations employed the growth rates of the associated cultures were not much different from those of the control strains.

In adjacent and mixed cultures the faster strain usually enveloped the slow growing strain and the latter appeared as sectors. For example in adjacent and mixed cultures of *Dendryphiella* and *Phoma*, *Dendryphiella* which is slightly fast growing occupied the major portion of the growth.

Mixed and adjacent cultures of *Dendryphiella* and *Phoma* were, however, exceptions. Although the former was decidedly fast-growing, it was the slow growing *Phoma* that dominated, and *Helminthosporium* appeared as small sectors in a major growth of *Phoma*.

The appearance of sectors as found in the above mixed cultures in isolated areas is interesting. Obviously these had their origin in the original inoculum, but their continuity was difficult to establish. Among the other features of interest were the behaviour in regard to the formation of colour and zonation in the mixed growths.

**Colour**—In the region where the young hyphae of *Monilia* and *Phoma* arising from inocula planted 2 cm apart came in contact with each other, there a few millimetres inside the growing edge of *Phoma* culture, was formed a single dark-red band very clearly visible in the substratum. As the faster *Monilia* colony started encircling the *Phoma*, the dark-red band appeared at the region of fresh hyphal contact, while the colour became fainter at the first place of appearance. The red band gradually moved further up where the younger hyphae of *Monilia* had come in contact with younger hyphae of *Phoma*.

When the entire *Phoma* colony was enveloped by *Monilia* and the younger hyphae of the latter occupied a position directly opposite to the first place of contact with *Phoma* the band moved to the new place of contact, the colour at the original place having disappeared

The formation of colour at the line of contact of two colonies is well known but the subsequent disappearance as noted here is peculiar

The fresh, younger hyphae of *Monilia* induces the formation of the dark-red band in *Phoma* colony. This must be due to the interaction of the staining products of the two colonies. The subsequent disappearance of the colour band may be attributed to the excess of a chemical substance due to its accumulation or to the formation of a new chemical by the older mycelium

*Zoning*.—In normal cultures *Phoma* and *Helminthosporium* produce zonation although *Dendryphiella* does not. When *Phoma* and *Helminthosporium* were inoculated adjacently to form a mixed growth *Helminthosporium* appeared as sectors. In the mixed growth the zonation of both *Phoma* and *Helminthosporium* persisted, the red concentric rings of the former forming almost an unbroken ring with dark bands of the latter. When the growth arose from the mixture of inocula, the important point observed was the complete absence of zonation in *Phoma* and the persistence of the same in *Helminthosporium*. The identical results were obtained with *Phoma* combined with *Dendryphiella*. In adjacent cultures *Phoma* zoned very well as in controls but in mixture culture zonations in *Phoma* were singularly absent

#### *Detailed Observations*

With a view to making a detailed investigation it was decided to concentrate on two strains, that is one pair of strains only, instead of the five pairs used for preliminary observation. In order to find out the best reacting strains all the six strains were inoculated individually in 0.1, 0.25, 0.5, 1.0 and 2.0 per cent malic acid in standard synthetic medium. *Dendryphiella* and *Fusarium* having proved more sensitive to the acids, were chosen for the investigation.

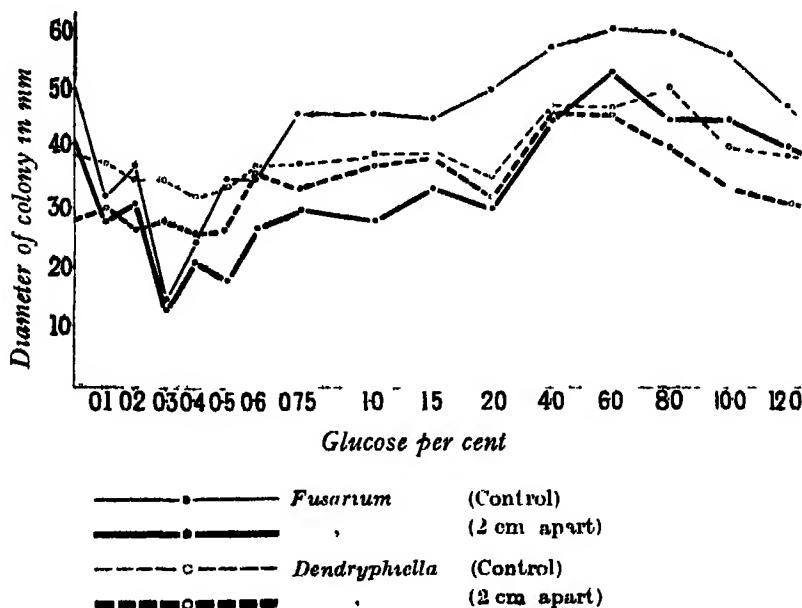
As has already been seen *Fusarium* and *Dendryphiella* are also easily distinguishable macroscopically by the striking difference in the mycelial colour—*Fusarium* being white and *Dendryphiella* dark-grey. Microscopically the difference lay in the hyphal characters and branching. Further profuse sporulation occurred in *Dendryphiella* where its growth met that of *Fusarium*. This last character particularly facilitated the detection of the boundary of

the *Dendryphiella* growth, especially in the case of partial and complete suppression. For these experiments the fungi were inoculated 2 cm apart and adjacently.

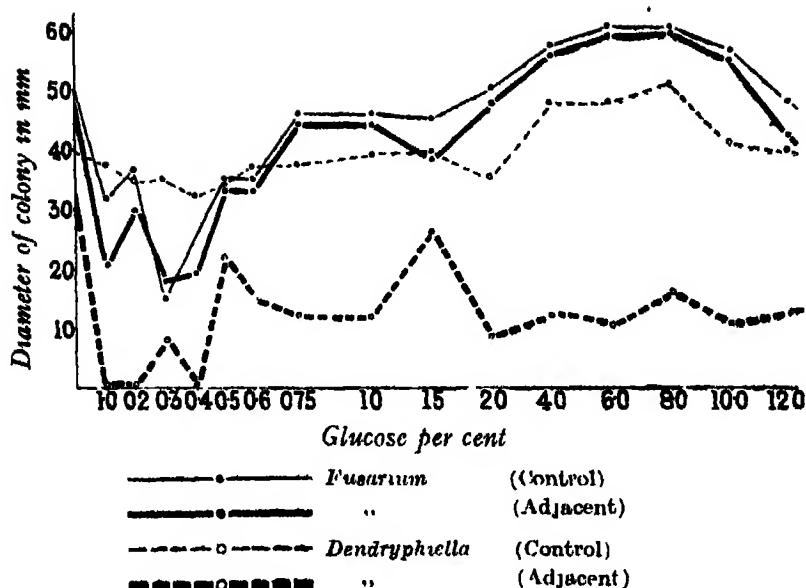
*Glucose series*—The combined effect of various salts in the standard medium having failed to yield much result, individual salts like glucose and potassium nitrate were tried in different concentrations using agar as the basal medium.

Glucose was added to 1.5 per cent agar in the strengths 0.1, 0.2, 0.4, 0.5, 0.6, 0.75, 1.0, 1.5, 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 per cent steamed instead of autoclaved for sterilization and plated. *Fusarium* and *Dendryphiella* were inoculated 2 cm apart and adjacent controls were kept.

The results are given in Text-Figs 2 and 3 where the diameters of six days growths are plotted against the glucose concentration for 2 cm apart and adjacent cultures respectively.



TEXT-FIG 2.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in glucose series. Inocula placed 2 cm apart.



Text-Fig 3.—Graphs showing the behaviour of the two fungi *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in glucose series inocula placed adjacently.

It will be seen from Text-Fig 2 that in the cultures where the fungi had been inoculated 2 cm apart

1 *Fusarium* and *Dendryphiella* are inhibited in the presence of each other as compared to the controls. Of these, however, *Fusarium* shows a greater inhibition than *Dendryphiella*.

2 At lower concentrations of glucose 0.1–0.6 per cent *Fusarium* has a lower growth rate than *Dendryphiella* both in control and in paired cultures. At 0.75 per cent *Fusarium* accelerates and throughout the higher concentrations employed, the one in control remains by far the fast growing.

3 In completing cultures at concentrations 0.3 to 4.0 per cent *Dendryphiella* has a faster growth rate than *Fusarium*, but beyond 4.0 it is the other way round.

4 At concentrations 0.1 to 0.6 per cent *Fusarium* and *Dendryphiella* colonies do not meet when inoculated 2 cm apart and the mycelia of the two growths thin out as they approach each other.

It will be seen from Text-Fig 3 that in adjacent culture

1 Throughout the series *Fusarium* and *Dendryphiella* are inhibited in the presence of each other as compared with the controls except in the case

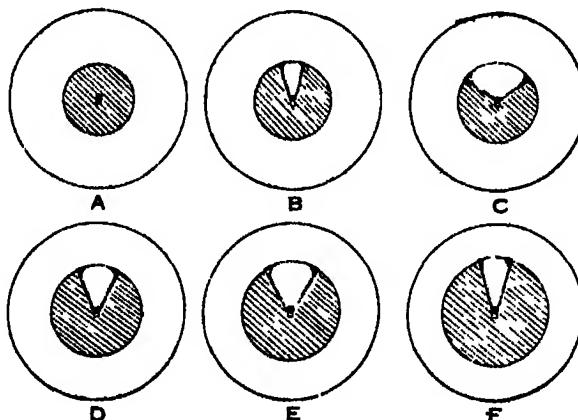
of *Fusarium* at 0.3 per cent. Of these however, *Dendryphiella* is very markedly inhibited by *Fusarium*.

2 *Fusarium* dominated throughout *Dendryphiella* in addition to being retarded has three points of complete inhibition at 0.1, 0.2 and 0.4 per cent. There is a slight growth at 0.3 per cent which probably is due to the associated *Fusarium* being slightly less active at that concentration. The almost complete inhibition at concentrations 0.1–0.4 is especially interesting since about that region *Dendryphiella* in the control has a faster growth than *Fusarium*.

3 As in the case of 2 cm-apart-culture from 0.75 per cent and beyond *Fusarium* outgrows *Dendryphiella*.

4 In competing cultures *Fusarium* always has a decidedly faster growth rate.

In Text-Fig. 4 is illustrated diagrammatically the dominance of *Fusarium* over *Dendryphiella* in adjacent cultures where Fig. 4 (A) indicates the complete



TEXT-FIG. 4 A-F.—Diagrammatic representation of the relative area occupied by *Fusarium* sp. and *Dendryphiella* sp. in various concentrations of glucose. Inocula adjacent.

Shaded area represents *Fusarium*

Unshaded area represents *Dendryphiella*

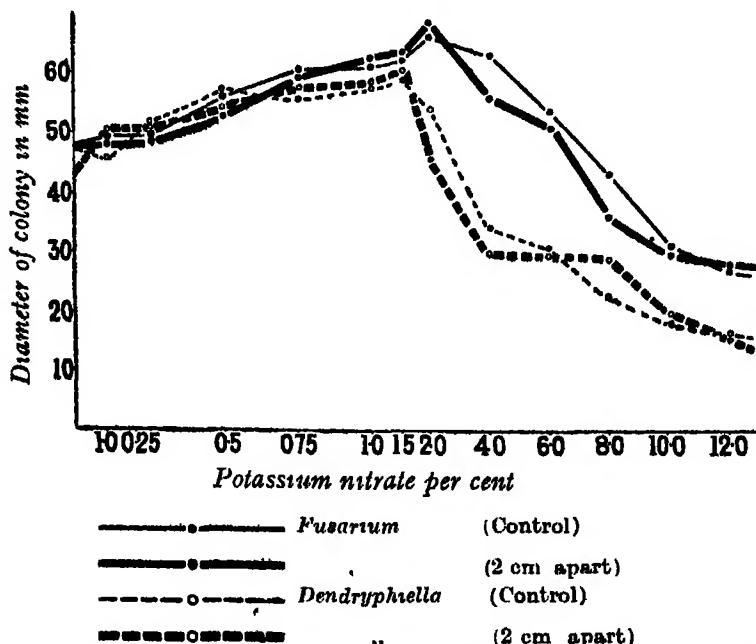
Dots indicate sporulation of *Dendryphiella*

- A. *Fusarium* and *Dendryphiella* inoculated adjacent in 0.1, 0.2 and 0.4% glucose showing complete suppression of *Dendryphiella*.
- B. Same strains in 0.5% glucose showing the appearance of *Dendryphiella*.
- C. Same strains in 1.5% glucose showing an acceleration of *Dendryphiella* growth over that in 0.5%.
- D. Same strains in 2.0% glucose showing an acceleration.
- E. Same strains in 4.0% glucose showing a retardation of *Dendryphiella*.
- F. *Dendryphiella* showing an acceleration over 4.0% with the addition of 8.0%.

inhibition of *Dendryphiella* as seen in 0.1, 0.2, 0.4% glucose, the fluctuations in the relative area occupied by the two strains in other concentrations are shown in Fig. 4 (A-F)

*Potassium nitrate series*—Potassium nitrate was next tried with 1.5 per cent agar in strengths 0.1, 0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0 per cent. *Fusarium* and *Dendryphiella* were inoculated 2 cm apart and adjacently. Controls were kept.

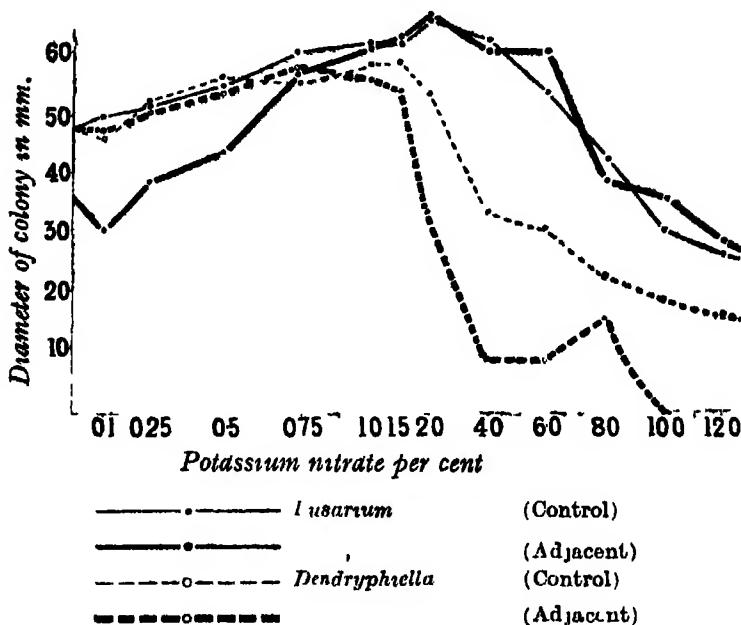
The results are given graphically in Text-Figs 5 and 6 where the diameters of six days growths are plotted against the potassium nitrate concentrations for 2 cm apart and adjacent cultures respectively.



TEXT-FIG 5.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in  $\text{KNO}_3$  series. Inocula placed 2 cm apart.

It will be seen from Text-Fig 5 that in cultures 2 cm apart, there was virtually no difference in the growth rates shown by *Dendryphiella*, *Fusarium* and their controls, up to the concentrations of potassium nitrate 0.1-1.5 per cent. Beyond this concentration *Fusarium* definitely takes upper hand, but nevertheless the fungi in associated cultures have almost similar growth rates to those of the controls, showing that the interaction of the two fungi has resulted into inhibition of growth rates only to an insignificant extent.

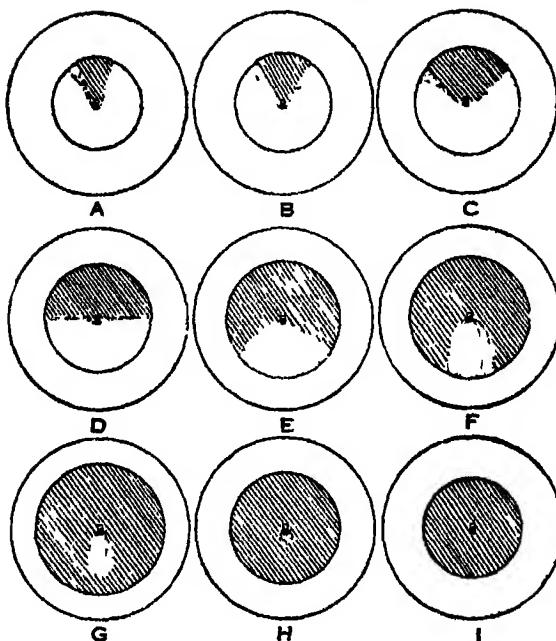
In adjacent culture (Text-Fig 6) in media up to the concentration of 0.75 per cent the growth rates of associated cultures and the controls are



TEXT-FIG 6.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in KNO<sub>3</sub> series. Inocula placed adjacently

almost the same except for that of *Fusarium* which shows a definite retardation. Beyond 0.75 per cent *Fusarium*, both in the control and in associated culture, is much faster than *Dendryphiella*. In concentrations 0.1 to 0.5 per cent *Dendryphiella* dominates *Fusarium*, they are almost equal at 0.75 per cent but beyond that concentration *Fusarium* completely dominates *Dendryphiella* as is shown by the difference in the growth rate between the two. At 4 per cent *Dendryphiella* shows very slight growth which is completely inhibited at 10 per cent although the control maintains a steady rate of growth. *Dendryphiella* seems to exert no influence up on *Fusarium* at relatively higher concentrations as judged from its rate of growth.

The domination of *Fusarium* by *Dendryphiella* in lower concentrations of potassium nitrate (0.1–0.5) and the domination of *Dendryphiella* by *Fusarium* in higher concentrations (1.0–10.0) and complete inhibition of the former by *Fusarium* in still higher concentrations are illustrated diagrammatically in Text-Fig 7 (A–I).



TEXT FIG 7 4-I.—Diagrammatic representation of relative area occupied by *Fusarium* and *Dendryphiella* in various concentrations of  $\text{KNO}_3$ . Inocula adjacent

Shaded area represents *Fusarium*

Unshaded area represents *Dendryphiella*

Dots indicate sporulation of *Dendryphiella*

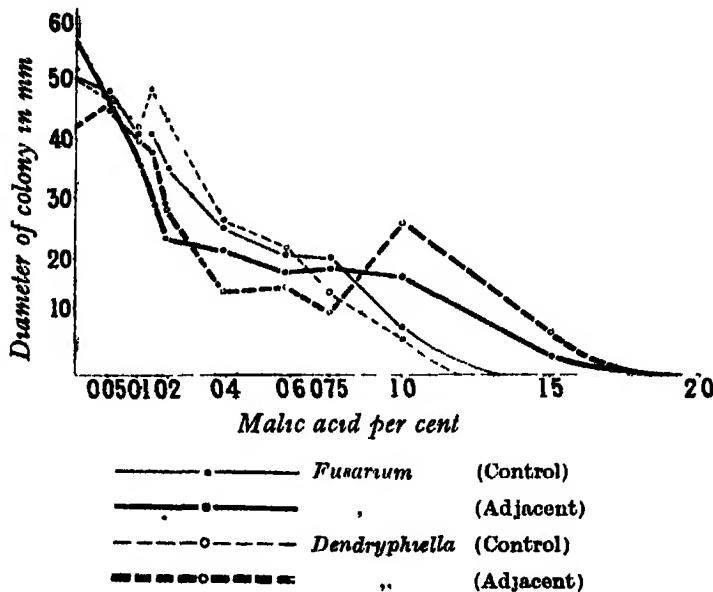
- A *Fusarium* recessive with a sectorial growth in 0.1% ;
- B *Fusarium* accelerates with addition of 0.25% ,
- C *Fusarium* further accelerates with addition of 0.5% :
- D *Fusarium* growth is equal to that of *Dendryphiella* growth in 0.75% ;
- E *Dendryphiella* retards and occupies a sector in *Fusarium* growth in 1.5% .
- F *Dendryphiella* further retards with addition of 2.0% ,
- G *Dendryphiella* occupies a still smaller part in 4.0% ,
- H *Dendryphiella* occupies a very small area in 6.0% and 8.0% .
- I Entire growth is that of *Fusarium* and there is no growth of *Dendryphiella* with addition of 10.0 and 12.0%  $\text{KNO}_3$  (Diagrammatic)

It is seen from Fig. 7 that *Fusarium* starts as a small sector in 1 per cent potassium nitrate (7A), increases in size with the increase in concentration (7B-7C), attaining the same size as *Dendryphiella* becomes reduced to a very small sector in 4 per cent (7G), still smaller in 6 per cent and 8 per cent (7H) till there is no growth of *Dendryphiella* at 10 per cent and 12 per cent. (7I, and Plate I, Figs 16-20)

*Acid series*—Malic acid was added to standard synthetic medium in strengths 0.025, 0.05, 0.1, 0.2, 0.3, 0.4, 0.6, 0.75, 1.0, 1.5, and 2.0 per cent and plated. *Fusarium* and *Dendryphiella* were inoculated adjacent and 2 cm apart. Controls were kept.

The results are shown graphically in Text-Figs 8 and 9 where the diameters of six days growths are plotted against acid concentrations for adjacent and 2 cm-apart-cultures respectively.

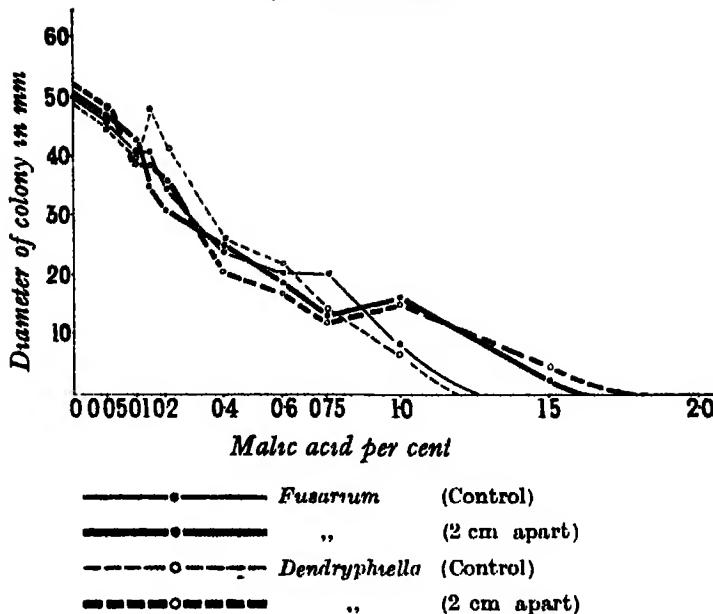
It will be seen from Text-Fig 8 that in adjacent culture *Dendryphiella* shows a marked increase in growth in 1 per cent to 1.75 per cent over *Fusarium* although in lower concentrations, it is either being dominated by



TEXT FIG 8.—Graphs showing the two fungi *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in Malic acid series. Inocula placed adjacently.

*Fusarium* or has a similar growth rate. In 2 cm-apart-culture (Text Fig 9), throughout the series the two fungi run closely parallel to each other and to the controls.

Far interesting is the fact that the controls of both the strains, *Dendryphiella* and *Fusarium*, stop growth at about 1.5 per cent acid. But when they are inoculated 2 cm apart and adjacent, the point of total inhibition is raised from 1.25 to 1.75 per cent. The result demonstrates a marked increase in the tolerance of acid due to the association of the strains.



TEXT-FIG 9.—Graphs showing the behaviour of *Fusarium* sp and *Dendryphiella* sp in associated culture and in control in Malic acid series. Inocula placed 2 cm apart

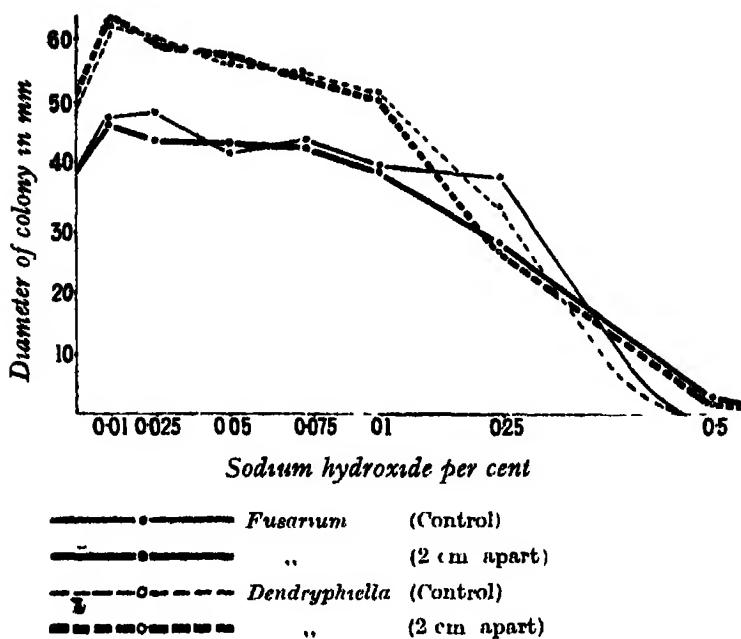
*Alkali series*—The effect of alkali on the competing strains was next tried by using sodium hydroxide and sodium carbonate

*Sodium hydroxide*—This was added to standard synthetic medium in the following strengths and plated 0.01, 0.025, 0.05, 0.075, 0.1, 0.25 and 0.5 per cent. Inoculations were made 2 cm apart and adjacently. Controls were kept

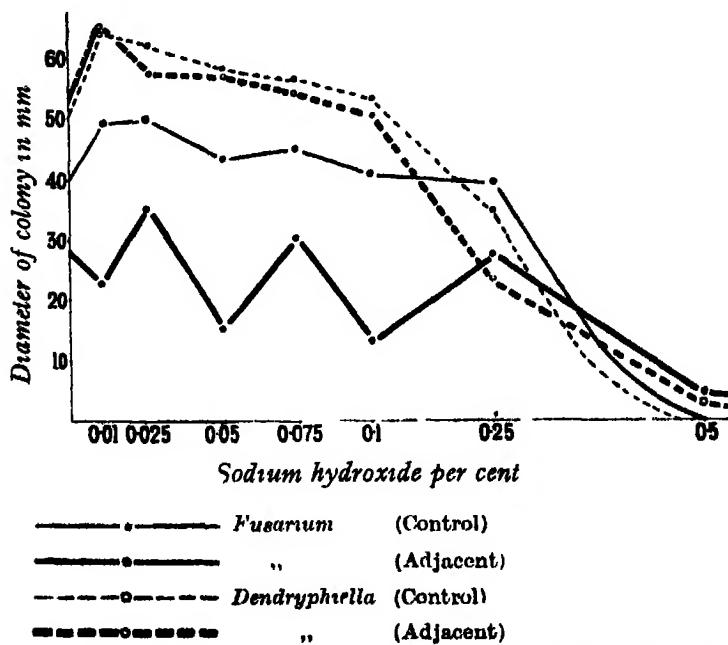
The results are shown graphically in Text-Figs 10 and 11 where diameters of six days growth are plotted against concentrations of sodium hydroxide for 2 cm apart and adjacent cultures

The behaviour of the strains in the series was very interesting. It will be seen from Text-Fig 10 that in cultures 2 cm apart *Dendryphiella* dominated in percentages 0.01, 0.025, 0.075 and 0.1, but all the time both growing slower than in controls. At 0.25 per cent the *Fusarium* so far slower than *Dendryphiella* becomes faster both in 2 cm-apart-culture and in the control, due to the sudden drop in the growth rate of the latter. At 0.5 per cent, when the controls have ceased to grow both the strains still continue with *Fusarium* somewhat dominating

In adjacent culture the reactions of the fungi are very similar to that for cultures 2 cm apart as already explained. In the latter case, however,



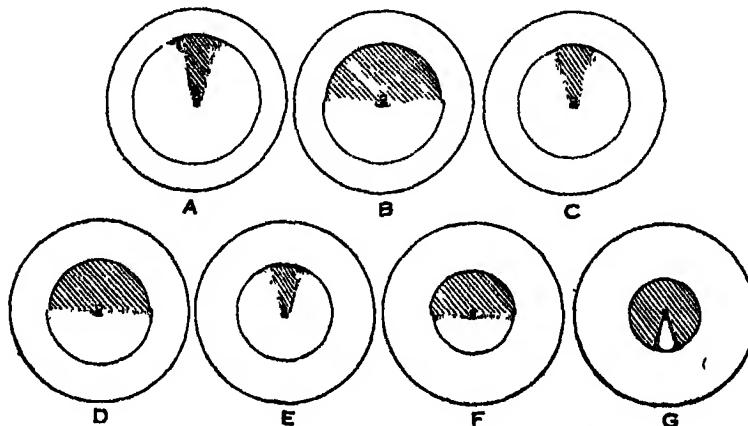
TEXT-FIG 10.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated cultures and in control in NaOH series. Inocula placed 2 cm apart



TEXT-FIG 11.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in NaOH series. Inocula placed adjacently.

*Fusarium* shows peculiar fluctuations, viz., acceleration at one strength and retardation at the next.

It will be seen from Text-Fig. 12 (A-G) that in a medium containing 0.01 per cent sodium hydroxide, *Fusarium* is confined to a small sector-like growth in a major growth of *Dendryphiella* [Text-Fig. 12 (A)]. In 0.25 per



Text Fig. 12 A-G — Diagrammatic representation of the relative area occupied by *Fusarium* sp. and *Dendryphiella* sp. in various concentrations of NaOH. Inocula adjacent

Shaded area represents *Fusarium*

Unshaded area represents *Dendryphiella*

Dots indicate sporulation of *Dendryphiella*

- A *Fusarium* occupies a small sector in a major growth of *Dendryphiella* with the addition 0.01% NaOH to the standard medium,
- B *Fusarium* accelerates with the addition of 0.025%,
- C *Fusarium* retards again with the addition of 0.05%,
- D *Fusarium* accelerates with 0.075%;
- E *Fusarium* again retards with addition of 0.1%,
- F *Fusarium* growth is more than that of *Dendryphiella* with 0.23%;
- G *Fusarium* dominates the growth and *Dendryphiella* occupies a sector at 0.5% NaOH (Diagrammatic)

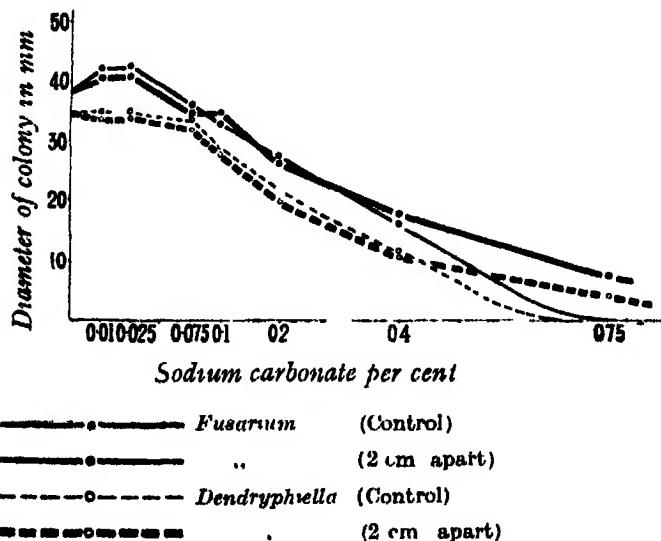
cent sodium hydroxide the two growths occupy equal area. In 0.05 and 1.0 per cent *Fusarium* is restricted to a small sector, while in concentration 0.075 per cent *Fusarium* outgrows *Dendryphiella* and occupies half the area of the entire growth and at 0.5 per cent dominates *Dendryphiella* completely restricting it to a very small sector.

A comparison of Text-Figs. 11 and 12 will show that in this case there is no correspondence between the relative growth of the two fungi and the

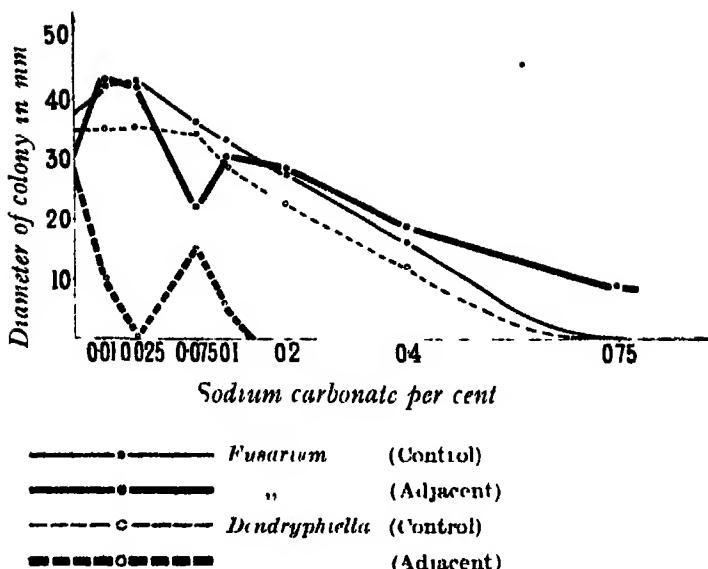
area occupied by them in adjacent cultures. It is seen from Text-Fig. 11 that in all concentrations up to 0.1 per cent *Dendryphiella* greatly dominates the *Fusarium*, having almost twice the growth rate, in spite of that *Fusarium* at 0.025 and 0.075 per cent of NaOH occupies area equal to that occupied by *Dendryphiella*, these are the concentrations when *Fusarium* shows accelerated growth.

It is interesting to note that in these series as in the others already mentioned, the associated fungi are capable of growth in higher alkali in adjacent culture and in culture 2 cm apart while they have ceased to grow in the control plates.

**Sodium carbonate**—This was tried in the following percentages with standard synthetic medium 0.01, 0.025, 0.075, 0.1, 0.2, 0.4 and 0.75. The two strains *Fusarium* and *Dendryphiella* were inoculated 2 cm apart and adjacent. The results are shown graphically in Text-Figs. 13 and 14 where diameters for six days growth of the competing strains and of the controls are plotted against various concentrations of sodium carbonate for 2 cm apart and adjacent cultures respectively.



TEXT-FIG. 13.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in  $\text{Na}_2\text{CO}_3$  series with inocula placed 2 cm apart.



Text Fig. 11.—Graphs showing the behaviour of *Fusarium* sp. and *Dendryphiella* sp. in associated culture and in control in  $\text{Na}_2\text{CO}_3$  series. Inocula placed adjacently.

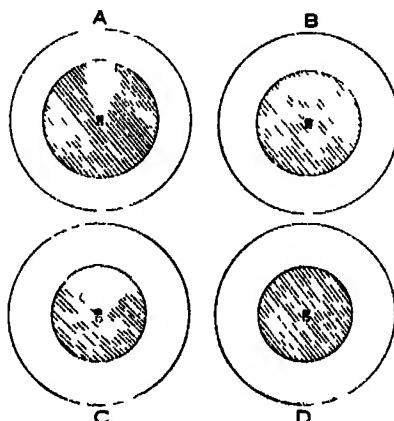
It will be seen from Text-Fig. 13 that in the concentrations of sodium carbonate employed *Fusarium* and *Dendryphiella* growing 2 cm apart do not show significant difference from the controls upto 0.4 per cent. At 0.75 per cent however, both the fungi continue to grow while there are no growths in the controls.

Particularly interesting results are seen in adjacent culture (Text-Fig. 14). In media containing 0.01 per cent and 0.025 per cent sodium carbonate *Fusarium* has the same growth rate as in the control, at 0.075 per cent there is a sudden drop. At 0.1 per cent of sodium carbonate the growth rate shows a marked increase and at 0.2 per cent it is again virtually the same as that of the control. At 0.4 per cent the competing *Fusarium* has a slightly higher growth rate and beyond that at 0.75 per cent where the growth of the controls has completely ceased, it continues to grow.

A comparison of *Dendryphiella* in control and in adjacent culture with *Fusarium* is still more interesting. In adjacent culture *Dendryphiella* has a much slower growth rate. A slight addition of sodium carbonate 0.01 per cent brings down the rate considerably and at 0.025 the growth of the fungus is inhibited. At 0.075 per cent *Dendryphiella* shows definite acceleration. *Dendryphiella* is finally inhibited at a concentration beyond 0.1

per cent sodium carbonate although growth in the control continues till 0.75 per cent.

The results are of great importance. They show a definite inhibitory influence exerted by *Fusarium* on *Dendryphiella*. In sodium carbonate concentration where *Fusarium* is active, *Dendryphiella* is considerably inhibited and with the decrease in the activity of *Fusarium*, *Dendryphiella* shows a corresponding increase. Beyond 0.1 per cent however, *Fusarium* completely checks the growth of the fungus.



TEXT FIG. 15 (A-D) — Diagrammatic representation of the relative area occupied by *Fusarium* and *Dendryphiella* in various concentrations of  $\text{Na}_2\text{CO}_3$ .  
Inocula adjacent.

Shaded area represents *Fusarium*

Unshaded area represents *Dendryphiella*

Dots indicate sporulation of *Dendryphiella*

- 1. *Dendryphiella* forms a sector in an entire growth of *Fusarium* at 0.01%.
- 2. Very little growth of *Dendryphiella* seen with the addition of 0.025%.
- 3. *Dendryphiella* accelerates with the addition of 0.075%.
- 4. There is no growth of *Dendryphiella* the dominant strain being *Fusarium* in percentages 0.1 to 0.75 of  $\text{Na}_2\text{CO}_3$ .

Text-Fig. 15 (A-D) will show diagrammatically the inhibitory influence exerted by *Fusarium* on *Dendryphiella* in sodium carbonate series. At 0.01 per cent and 0.075 per cent *Dendryphiella* forms a small sector, at 0.025 per cent it is restricted to a very small area near the centre, at 0.075 per cent it occupies a much bigger area and is completely inhibited at 0.1 per cent.

#### *Discussion*

A certain amount of work has been done on the growth of fungi in mixed culture Harder (1911), Cook (1924), Porter (1924), Machacek (1928),

Vanin and Vladimirskey (1932), Endo Sigeru (1932, 1933) and others have worked on different aspects of the problem

Harder has given a detailed account of changes in the rate of growth, in hyphal structures, of the formation of colouring matter, phenomenon of aversion, etc., in mixed cultures of a number of strains. He has also demonstrated that one mycelium does not kill another. Vanin and Vladimirskey (1932) have shown that in the mixed cultures of *Merulius lacrymans* and *Coniophora cerebella*, at an early stage, the mycelium of each grows normally without interfering with each other. Later the mycelium of *Merulius lacrymans* outgrows that of *Coniophora cerebella* causing a considerable retardation in the growth of the latter. Endo Sigeru (1932) has shown that the presence of micro-organisms is one of the factors controlling the sclerotial formation in *Sclerotium oryzæ-sativæ*. The inhibition and retarding action of one fungus on another in mixed culture have been worked out in detail by Porter (1924). Cook (1924) has made an interesting study on the succession of fungi in artificial culture and Machacek (1928) on the association of phytopathogens.

On the applied side of the problem Endo Sigeru (1933) has found that the antagonistic action of several organisms prevented appearance of a disease due to *Hypochnus Sasakii Shirai*. Vasudeva (1930) has demonstrated that the parasitic activity of a fungus is greatly retarded by the presence of a non-parasitic fungus and Asthana (1936) has found some interesting results on the effect of various fungi on the parasitic vigour and other characteristics of *Botrytis cinerea*.

The problem is approached from altogether a different view-point in this investigation. An attempt has been made here to find out how two fungi will behave in different growth conditions in associated cultures when they are grown contiguously or a little distance apart and how will they influence each other's growth.

It is evident from the various experimental data given that fungi are influenced not only by the change in the composition of the medium but also by the association of one strain with the other. A profound alteration in growth reactions occur when these are grown adjacently and 2 cm apart in altered condition of the medium.

Where a fast-growing strain was paired with a relatively slow-growing one, it was usually the faster strain that outgrew and enveloped the slower one, but reverse condition was also found where the slow-growing *Phoma* strain in mixed and adjacent cultures had completely dominated the faster *Helminthosporium* restricting it to small sectors.

It is in the detailed investigation of the behaviour of *Fusarium* and *Dendryphiella*, however, that more interesting results were obtained.

The domination of one strain over another as seen from the extent of area occupied by the competing strains of *Fusarium* and *Dendryphiella* in a mixed growth arising from inoculation either put adjacently or 2 cm apart, in various concentrations of the chemicals employed is very instructive.

*Fusarium* is only slightly faster than *Dendryphiella* in standard medium. Nevertheless in almost all the series so far employed, glucose, potassium nitrate, sodium carbonate and sodium hydroxide as the concentration was increased *Fusarium* gradually dominated *Dendryphiella* in adjacent culture. In the highest concentration of potassium nitrate and sodium carbonate employed the growth was all *Fusarium* to the total inhibition of *Dendryphiella*.

The details of reaction in different series, however, differed to a large extent. In glucose, for example, there were three inhibition points at relatively low concentrations of 0.1, 0.2 and 0.4 per cent where *Dendryphiella* was totally suppressed. But at 0.2 per cent, however, there was a certain amount of growth of *Dendryphiella*, which probably is due to the associated *Fusarium* being slightly less active at that concentration.

In subsequent concentrations, *Dendryphiella* occupied a relatively small sectorial area throughout and was never again completely suppressed even in the highest concentration employed. In sodium carbonate series too the major growth of *Fusarium* contained a sector of *Dendryphiella* whose area fluctuated in higher concentrations. *Dendryphiella* was completely inhibited in concentrations 0.15-0.75 per cent.

In potassium nitrate series it is the *Fusarium* that appeared as a small sector, which gradually became larger as the concentration of potassium nitrate increased finally suppressing the entire growth of *Dendryphiella*.

The result in sodium hydroxide series, however, was more complicated. *Fusarium* appeared as a small sector at the lowest concentration. But instead of a steady increase in the area with the increase in the concentration of sodium hydroxide there was alternate rise and fall. A semi-circular area in one concentration was followed by a small sector in the next till at 0.5 per cent *Fusarium* dominated the growth and restricted *Dendryphiella* to only a small sector.

A comparison of the results indicates that on the whole, the reaction of one strain against another is more pronounced in adjacent than in 2 cm.-apart-culture.

*The influence of Fusarium and Dendryphiella upon each other* is well manifested in the difference between the growth rates of the strains in associated culture on one hand and their controls on the other. The growth rate of a fungus depends upon the chemicals constituting the media and their concentrations, but the reaction of the competing strains to the media is also profoundly modified by the association of one fungus with the other. The modification in growth rate results in either retardation or acceleration.

The acceleration of growth rates of the competing fungi in associated cultures was primarily observed in higher concentration of chemicals. For example, both *Fusarium* and *Dendryphiella* showed acceleration over their controls beyond 0.4 per cent sodium hydroxide in adjacent culture, and in the same concentration of sodium carbonate in cultures 2 cm apart. In malic acid series it was found only in concentration as high as 0.75 per cent and over. Comparatively lower concentration may also bring out the same result. Thus *Fusarium* showed faster growth rate in adjacent culture beyond 0.1 per cent sodium carbonate.

The acceleration of growth raises the final inhibition point of the strains. The strains in these cases maintained their growths in concentrations where the controls had ceased to grow. It was found in all the series except that of glucose. For example, in malic acid series while the controls failed to grow at about 1.25 per cent both *Fusarium* and *Dendryphiella* continued to grow at 1.5 per cent and had respectively diameters of 3.0 mm and 7.0 mm in adjacent culture and 2.5 mm and 5.0 mm in 2 cm-apart-culture. Similarly in sodium hydroxide series at 0.5 per cent while control had failed to grow altogether, *Fusarium* and *Dendryphiella* had diameters 3.0 mm and 2.0 mm respectively in cultures 2 cm apart, and 5.0 mm and 3.0 mm respectively in adjacent culture. In sodium carbonate again at 0.75 per cent in 2 cm-apart-culture *Fusarium* and *Dendryphiella* had diameters of 7.0 mm and 4.0 mm respectively while controls showed no growth. At the same concentration, in adjacent culture diameter of *Fusarium* proved to be 9.0 mm against no growth of control, *Dendryphiella* had stopped growth at 0.15 per cent sodium carbonate.

*The retardation of growth rates of the competing fungi* was usually observed in the lower concentrations and sometimes throughout the series.

In malic acid there was retardation for both the strains in concentrations between 0.01-0.75 per cent. In sodium hydroxide, the strains growing 2 cm apart had a slightly slower growth rate in lower concentrations, in adjacent culture only *Fusarium* was strongly retarded below 0.4 per cent. In sodium carbonate in 2 cm-apart-culture, *Fusarium* and *Dendryphiella*

were both retarded below 0.4 per cent while the limit for the same in adjacent culture was 0.1 per cent. The degree of retardation, however, varied. This was evident in all concentrations of potassium nitrate. In glucose series too, in adjacent culture, there was a slight retardation throughout *Dendryphiella*. On the other hand, showed slight fall in growth rate in 2 cm-apart culture which became very marked in adjacent culture with inhibition points at 0.1, 0.2 and 0.4 per cent concentrations.

The retardation culminating in the complete suppression of *Dendryphiella* by *Fusarium* occur at 0.15 per cent sodium carbonate while the diameter of the control is 25.0 mm. There is a similar and equally striking inhibition of *Dendryphiella* at 10 per cent potassium nitrate when the control fungus shows a diameter of 20.0 mm.

It is possible that the media in the neighbourhood of the growths become modified, either to the advantage or to the disadvantage of the strains by the staling substances produced by them and the observed differences in the growth rates are due to the differential reaction of the strains to these modified media. Or as it has been suggested by Machacek (1928) the differences may be due to unequal assimilation of available food from the media causing the starvation of one organism.

That these factors play an important role in the growth reactions of fungi is well known, but it is not improbable that actual contact (Das Gupta, 1934) or the mere presence of hyphae may, to a certain extent, be responsible for some of the observed results.

At particular strengths of sodium carbonate (0.2, 0.4 and 0.75 per cent) in adjacent cultures the retarding influence of *Fusarium* was so great that *Dendryphiella*, in spite of having a favourable growth rate in the controls, is totally suppressed by *Fusarium*. In such a condition where there was no growth of *Dendryphiella* the accelerated growth of *Fusarium* over its control could not possibly be due to diffusion of staling products from *Dendryphiella*. It may be concluded therefore that at least in certain media even the mere presence of an inoculum of *Dendryphiella* placed adjacently to that of *Fusarium* has a striking effect on the acceleration of growth of the latter.

It is apparent from the study of the results obtained from different series of experiments that growth reaction of associated non-parasitic fungi as represented by two strains under consideration, are extremely variable. They show various degrees of tolerance and inhibition. Machacek (1928) distinguished several types of association on the basis of mutual reaction, viz., (1) one organism causes complete inhibition of its associates; (2) associated organisms are mutually tolerant on each other and so on. Results here

show, however, that no hard and fast rule can be laid down, in fact, inhibition, tolerance, etc., as shown by the fungi are but functions of the chemical composition of the growth medium which are profoundly modified by the interaction of the organisms upon each other

### *Summary*

In order to ascertain the nature of growth reactions in associated cultures of non-parasitic fungi six strains were used in five different combinations

*Fusarium* sp and *Dendryphiella* sp, *Fusarium* sp and *Gibberella* sp, *Phoma* sp and *Helminthosporium* sp, *Phoma* sp and *Monilia* sp, *Phoma* sp and *Dendryphiella* sp

The paired strains were inoculated mixed, adjacent and 2 cm apart in media differing in composition of acid, alkali and nutritive chemicals and their reactions were studied. Detailed work was done only with one pair *Fusarium* sp and *Dendryphiella* sp. Some of the more interesting results are given below

In the majority of cases usually the faster strain of a pair enveloped the slower one and the latter appeared as sectors. But *Phoma*, a slow growing strain, was found to dominate the faster strain of *Helminthosporium*.

*Dendryphiella* and *Fusarium* showed differential reaction to the various media employed. There was also a pronounced influence of each fungus on the other as judged from the relative area occupied by these in mixed growth as well as from their growth rate.

The domination of one strain over another as indicated by the extent of area occupied by the competing strains of *Dendryphiella* and *Fusarium* in adjacent and 2 cm-apart-culture varied with the composition of media employed. Generally in lower concentrations *Fusarium* appeared as major growth with *Dendryphiella* as sector. In some cases *Fusarium* appeared as a small sector in the major growth of *Dendryphiella*. Ultimately, however, in all the series in relatively higher concentrations, it was always the *Fusarium* that dominated the growth, sometime to the complete inhibition of *Dendryphiella*.

The accelerating influence of *Fusarium* and *Dendryphiella* upon each other was manifest at comparatively higher concentrations and rarely at lower, where *Fusarium* and *Dendryphiella* both accelerated over their controls both in adjacent and 2 cm-apart-culture. The immediate, important result of the acceleration was the raising of the final inhibition point of the strains in almost all the series. Here the individual strains in associated

cultures continued to grow in media where controls had ceased to grow altogether

The retarding influence of *Fusarium* and *Dendryphiella* upon each other was evident in the lower concentrations. It was more pronounced in adjacent culture. *Dendryphiella* was more influenced by *Fusarium* than *Fusarium* by the former. In glucose, in adjacent culture, *Fusarium* totally inhibited the growth of *Dendryphiella* at three low concentrations (0.1, 0.2 and 0.4 per cent). The most interesting was the complete inhibition of *Dendryphiella* by *Fusarium* at 0.15 per cent sodium carbonate and 10.0 per cent potassium nitrate in adjacent cultures although in control *Dendryphiella* showed diameter of 25.0 mm and 20.0 mm respectively.

There is a suggestion that the presence of a mere inoculum of one fungus may also, in certain cases, modify the growth reaction of another.

I wish to express my grateful thanks to Dr S N Das Gupta for suggesting the problem and offering me ready guidance and criticism throughout

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#### DESCRIPTION OF PLATE FIGURES

Figs 16-20 — Photographs showing the behaviour of *Fusarium* sp and *Dendryphella* sp when grown adjacently in various concentrations of  $\text{KNO}_3$ . The darker colony represents *Dendryphella*  $\times \frac{1}{2}$

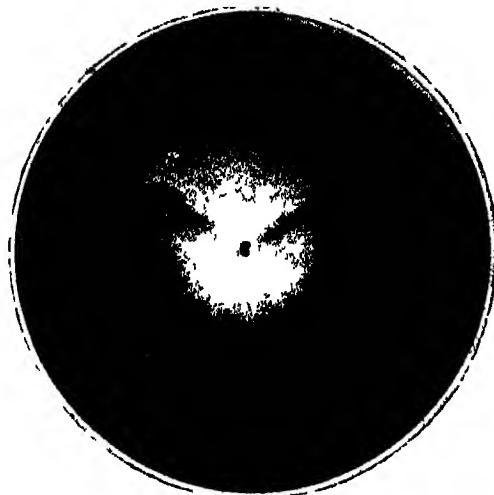
FIG 16 0 25%  $\text{KNO}_3$ , *Dendryphella* occupies major area and *Fusarium* a small sector

FIG 17 0 75%  $\text{KNO}_3$ , *Dendryphella* and *Fusarium* occupying equal area

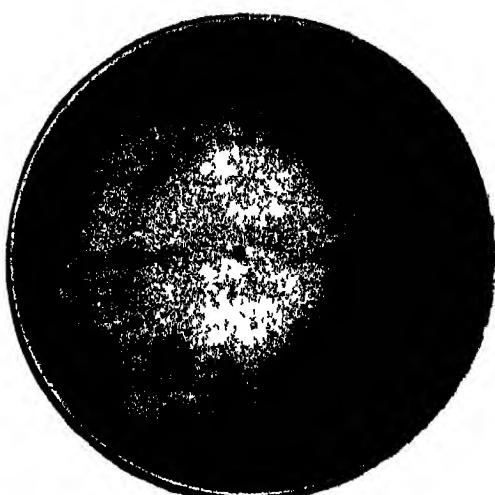
FIG 18 1%  $\text{KNO}_3$ , *Fusarium* occupying major area

FIG 19 2%  $\text{KNO}_3$ , *Fusarium* occupying still greater area and *Dendryphella* forming a sector

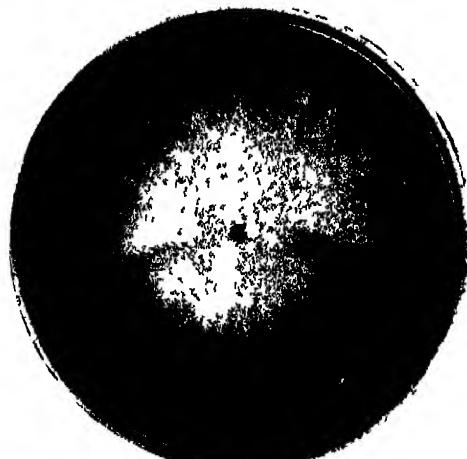
FIG 20 6%  $\text{KNO}_3$ , *Fusarium* completely dominating *Dendryphella* restricted to a small growth near the inoculum (dark)



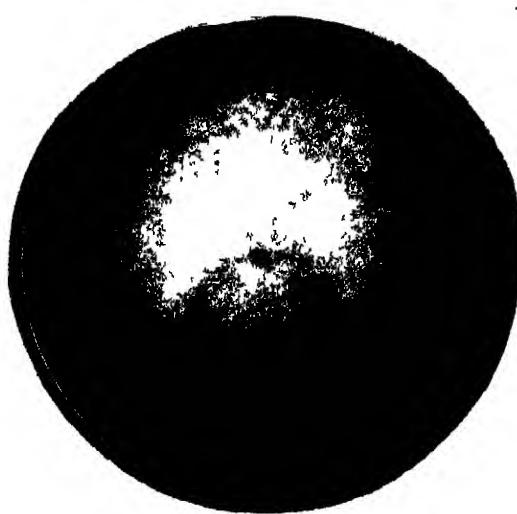
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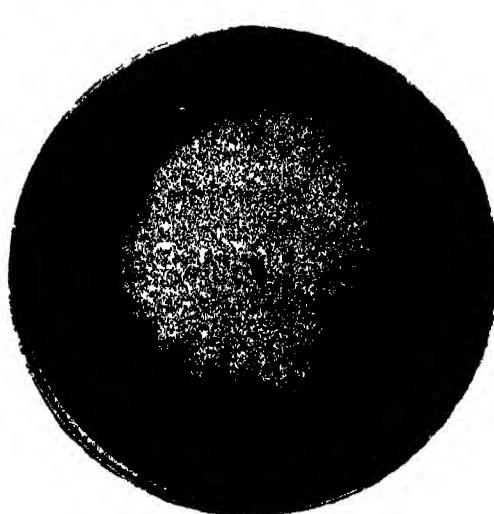
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# EFFECTIVENESS OF CHEMICAL FERTILISERS ON THE GROWTH AND WATER REQUIREMENT OF WHEAT

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Received November 22, 1938

## *Introduction*

IN the previous contributions from this Experiment Station on the problem of water requirement of a large number of crop plants<sup>10 11</sup> besides the specific and varietal differences and the critical periods, the influence of yield and duration of life-cycle of the plants and also of the soil-moisture on their water requirement were studied in detail. In this communication are presented the results of experiments on the effectiveness of certain chemical fertilisers on the growth and water requirement of wheat.

With the increasing application of fertilisers in the successful production of crops, the problem of water requirement is becoming more and more complicated, this being particularly true when the varied after-effects of dressings are studied in conjunction with the water relations of the plants. Another problem of considerable importance is the requisite supply of water, both as regards the amount and the opportune moments, when the fertilisers are added so that the maximum growth and yield of the crop may be obtained—a problem on which no detailed information is yet available. In an early investigation on the problem of water requirement Lawes<sup>4</sup> found that the water requirement of certain plants, specially peas, clover and wheat was diminished whereas that of others, e.g., barley and beans was considerably increased in response to manuring with chemical fertilisers. Sachs<sup>5</sup> observed a similar depression in transpiration rate when potassium nitrate and ammonium sulphate were added to soils. A distinct economising effect on the water requirement of white mustard in response to the addition of potash specially in soils containing smaller amounts of water was observed by Maercker<sup>6</sup> while Hartwell and his co-workers<sup>7</sup> recorded an increase in transpiration of wheat seedlings due to the addition of potassium chloride (*cf.* Gardner<sup>8</sup>). Reed,<sup>9</sup> on the other hand, noted that transpiration was increased on the addition of lime and sodium phosphate whereas the reverse

effect was observed in the case of potassium sulphate and sodium nitrate Leather<sup>6, 8</sup> working under Indian conditions, compared the water requirement of a number of crop plants supplied with and without manures and found a decline of the same in the manured ones His figures for all the crops in general, are, however, much higher than those obtained at this Station<sup>10</sup> apparently due to the unsuitability of his experimental technique of estimating transpiration

It is thus apparent that this problem of water requirement of crops in relation to dressings with different artificial fertilisers awaits further detailed and critical study since variations in the effect of the different fertilisers on one plant and also of a single fertiliser on different plants are of common occurrence Investigations were therefore conducted using the improved methods of experimentation to elucidate the effects of certain important fertilisers, e.g., ammonium sulphate, ammonium phosphate, superphosphate, potassium sulphate and potash mixture on the growth and water requirement of wheat under the semiarid tropical conditions of this locality and are reported in the present paper

#### *Procedure*

Pure strain seeds of wheat var Pusa 12 of as nearly uniform size, weight and relative density were grown in porous earthenware pots, 9 x 12 inches in size, to ensure proper soil aeration Air-dry and well-sieved farm soil was thoroughly mixed with each fertiliser separately at the rate of 1.3 gm per 10 kgm of soil The weight of one acre foot of the farm soil was then determined and the quantity of fertiliser added calculated in terms of lbs of N<sub>2</sub>, P<sub>2</sub>O<sub>5</sub> or K<sub>2</sub>O added per acre The amounts of nutrients added as lbs per acre is shown in Table I Before packing the pots, the mixed soil was damped a bit with a little quantity of water The pots containing these soil-manure mixtures were then grouped into several sets according to the nature of the manure added

To ensure homogeneous growth under as natural conditions as possible and also to obtain the best conditions of nutrition the potted plants were buried upto the height of the pots in soil-fertiliser mixture of the same proportion as that in the particular set of pots in shallow trenches lined with bricks side by side with the field plants

At successive intervals six of the experimental pots selected at random were taken out and sealed air-tight in metal containers with wax-petrolatum mixture after the manner indicated in an earlier publication from this Research Station<sup>10</sup> Every morning the loss incurred through transpiration

TABLE I  
*Influence of fertilisers upon the growth of wheat*

Plant characteristics	Control	Ammonium phosphate (N <sub>2</sub> P <sub>2</sub> O <sub>5</sub> )*	Ammonium sulphate (N <sub>33</sub> )	Potassium sulphate (K <sub>77</sub> )	Super-phosphate (P <sub>66</sub> )	Potash mixt (N <sub>16</sub> , K <sub>16</sub> , P <sub>16</sub> )	Significant difference P = 0.05
Height per plant, cm	65.83	108.52	108.82	80.54	82.04	89.21	8.52
Tiller number per plant	3	8	7	5	6	7	1.64
Dry weight per plant, gm	14.34	23.71	22.83	16.99	18.18	19.36	1.92
Yield of grain per plant, gm	4.23	8.53	7.73	5.44	6.04	6.74	2.21
Yield of straw per plant, gm	10.11	15.18	15.10	11.55	12.14	12.62	2.56
Length of head, cm	5.43	12.24	11.79	6.01	9.27	10.17	2.60
Weight of 100 grains, gm	4.43	6.98	6.01	5.74	5.41	6.03	1.42
Volume weight of grains per c.c., gm	0.72	0.93	0.91	0.83	0.85	0.86	.
Leaf area per plant, sq. cm	14.96	28.25	25.12	17.53	19.78	20.06	
Time of blossoming, days after sowing	58	63	63	60	60	58	
Duration of floral development, days	20	23	23	21	20	23	.
Time of fruiting, days after sowing	78	86	86	81	80	81	..
Time of harvest, days after sowing	103	111	111	106	105	106	

\* This indicates that nitrogen and P<sub>2</sub>O<sub>5</sub> are added at the rate of 33 lbs per acre. Similar figures for the other treatments indicate the same in respect to the active constituents.

was recorded and the soil-moisture was brought to the original level by the addition of the equivalent quantity of water. The moisture content of the soil was determined at intervals of seven days. This was done by taking representative samples of known weight from different pots and drying in steam oven at 100° C. The loss incurred in drying was calculated in terms of percentage loss on dry weight basis. It would appear from the values of moisture content thus obtained (Table II) that the plants were growing under 22% soil moisture content since the very beginning of the age-cycle, thus ensuring optimum moisture conditions for studies on the water requirement of cereals.<sup>11</sup>

A full record of meteorological observations was maintained at this Research Station. The evaporating power of the atmosphere was also

TABLE II

*Moisture content of soil at successive stages of age-cycle*

Sample No	Date	Fresh weight of composite sample	Dry weight of composite sample	Moisture content per 100 gm of soil	Moisture-holding capacity of soil	Moisture content on percentage water holding capacity basis	Evaporation per hour in gm per 1000 sq cm
1-6	15-11-1935	12.12	9.04	22.21	58.13	38.27	
7-12	22-11-1935	12.02	9.38	22.00	57.92	37.99	25.68
13-18	20-11-1935	12.18	9.56	21.54	58.90	37.13	25.65
19-24	6-12-1935	12.19	9.59	21.32	57.54	37.05	25.62
25-30	13-12-1935	11.81	9.16	22.45	58.77	38.20	
31-36	20-12-1935	12.35	9.02	22.07	58.29	37.87	24.52
37-42	27-12-1935	12.01	9.35	22.13	58.08	38.11	
43-48	3-1-1936	12.32	9.63	21.97	57.03	38.00	
49-54	10-1-1936	12.22	9.49	22.37	58.55	38.21	
55-60	17-1-1936	11.85	9.23	22.12	58.03	38.12	24.50
61-66	24-1-1936	12.20	9.48	22.43	57.63	38.92	
67-72	31-1-1936	11.93	9.33	21.78	57.50	37.89	25.63
73-78	7-2-1936	11.99	9.41	21.53	57.09	37.71	26.66
79-84	14-2-1936	11.89	9.23	22.35	58.47	38.22	26.69
85-90	21-2-1936	12.11	9.49	22.25	58.09	38.31	27.12
91-96	28-2-1936	12.15	9.46	22.20	58.39	38.02	29.32

recorded from a shallow water pan and used for estimating how far transpiration at successive stages of growth was related to the evaporating power of the atmosphere. The seeds were sown on 15th November 1935 and the crop harvested between 6th March to 14th March 1936.

As during the previous studies<sup>10,11</sup> the evaporation of water from soil under similar conditions of atmospheric variables was also measured during the period of experimentation. The total amount of water required for a successful wheat crop in terms of gallons and acre inches was finally calculated after taking into account the water transpired by the plant and that evaporated from the soil during the life-cycle of the crop.

Opportunities were also availed to study the response of the crop to the addition of the different fertilisers. Thus, the variations in the morphological characteristics of the differently treated plants and also their dry matter accumulation were noted at successive stages of their life-cycle and were utilised to evaluate the influence of the manurial treatments both on the growth and water requirement of the crop. The final yield of the plants were also similarly noted. Statistical treatments consisted in analysing the same by the Fisher's method of analysis of variance.

### *Experimental Results*

#### *Growth Characteristics—*

In consequence of the addition of the fertilisers distinct beneficial effects on the growth of the plants are noted, prominent variations from treatment to treatment in the morphological characteristics appearing soon after the establishment of the seedlings. Statistical analysis of the data of the various characteristics collected at the final stage (Table I) indicate that in general the treatments have given significantly better results than the control series.

In all the treatments, the height of the plants increases significantly, the best result being shown when  $N_{33}P_{33}$ \* (ammonium phosphate) is added. Nitrogen alone ( $N_{33}$ ) given as ammonium sulphate gives better results than  $P_{66}$  (superphosphate),  $K_{77}$ , (potassium sulphate) and  $N_{16.5}K_{18}P_{16.5}$  (potash mixture) although this last treatment is significantly better than the other two. Similarly, the tiller number is also significantly increased in response to the addition of the fertilisers.  $N_{33}P_{33}$  (ammonium phosphate) again shows the best result which is also better than K and P added alone.  $N_{33}$  (ammonium sulphate) and  $N_{16.5}K_{18}P_{16.5}$  (potash mixture) in this case show similar results and are better than K applied alone.

The period when the blossoms appear for the first time is slightly delayed in response to the different treatments as compared to the control plants except when  $N_{16.5}K_{18}P_{16.5}$  (potash mixture) is applied. This delay is only two days for  $K_{77}$ , (potassium sulphate) and  $P_{66}$  (superphosphate) and five days for  $N_{33}$  (ammonium sulphate) and  $N_{33}P_{45}$  (ammonium phosphate) series. Similarly, the manured plants require 1–3 days more for their floral development except in the case of  $P_{66}$  (superphosphate) applied alone. The time when the fruits appear for the first time is also delayed in the manured plants, a maximum delay of 10 days being noticed in the cases of

\* This indicates that nitrogen and  $P_2O_5$  are added at the rate of 33 lbs. per acre. Similar figures have been used in the paper for the other treatments also.

$N_{16}$  (ammonium sulphate) and  $N_{16}P_{16}$  (ammonium phosphate). Finally, the manured plants are ready for harvest 2-8 days later than the control plants, the latter being again necessary for both the ammonium treated series.

In response to the addition of the fertilisers except when K is applied alone (potassium sulphate) the length of the head is also increased significantly.  $N_{16}P_{16}$  (ammonium phosphate) shows the best result and is better than K and P applied alone. The absolute weight of the grains is also significantly increased except again in the cases when K and P are applied alone, there being no significant differences between the  $N_{16}$  (ammonium sulphate),  $N_{16}P_{16}$  (ammonium phosphate) and  $N_{16}, K_{16}P_{16}$  (potash mixture). The volume weight of grains also shows similarly better results with the N and NP series.

The yield of the grains and straw per plant also varies considerably with the different fertiliser treatments. K (potassium sulphate) and P (superphosphate) applied alone do not however show any significant increase in the yield of the grain while these two treatments along with NKP (potash mixture) also indicate the same when the straw yield is considered. N and NP (ammonium sulphate and phosphate) give best yield of grain, while the former is better than K (potassium sulphate) the latter one shows higher yield than both K (potassium sulphate) and P (superphosphate). The NKP combination (potash mixture), however, missed the level of significance in the case of straw yield by a very narrow margin.

Although the growth of the crop is best in N (ammonium sulphate) and NP (ammonium phosphate) series in all respects, the chief disadvantage of these series lies in the fact that the plants are often prone to lodging while this is minimised in the  $K_{16}$  (potassium sulphate) series and characteristically absent in the other two series.

The dry weight of plants when plotted against age gives the usual sigmoid type of curve (Fig. 1). The curves in general rise gradually to a maximum becoming more marked with the different treatments after the 56th day and show later the maintenance of the definite gradation. A statistical analysis of the final dry weight per plant of the differently treated sets shows a significant increase with all the treatments, the best results being shown by  $N_{16}P_{16}$  (ammonium phosphate) and  $N_{16}$  (ammonium sulphate) which are also better than K, P and NKP treatments.

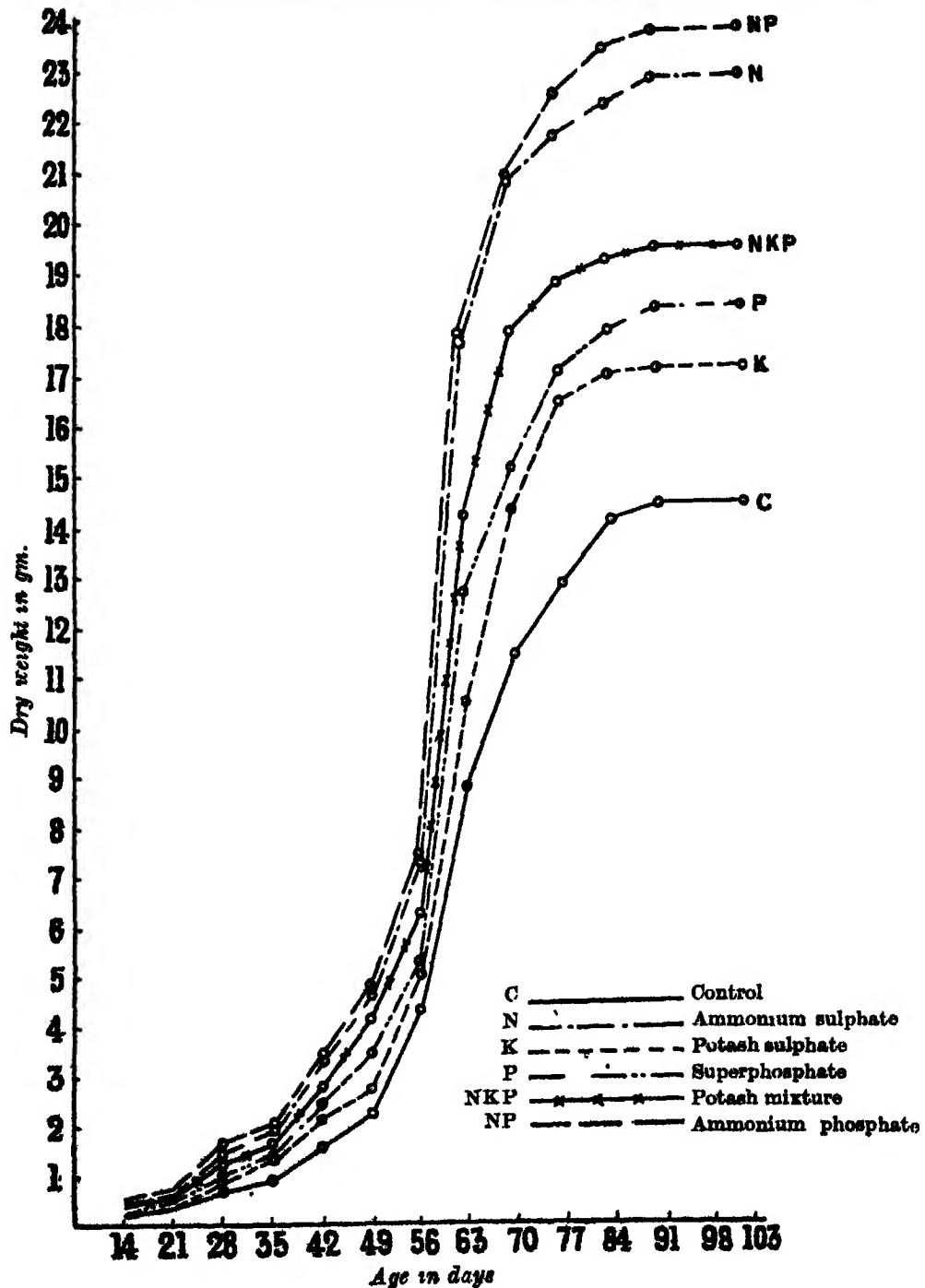


FIG. 1  
Growth of wheat as influenced by fertiliser treatments

When the relative growth rates at successive stages of the life-cycle of the plant are considered (Fig. 2) three characteristic peaks are noticed in the treated and also in the control plants. Of the three maxima the first one is

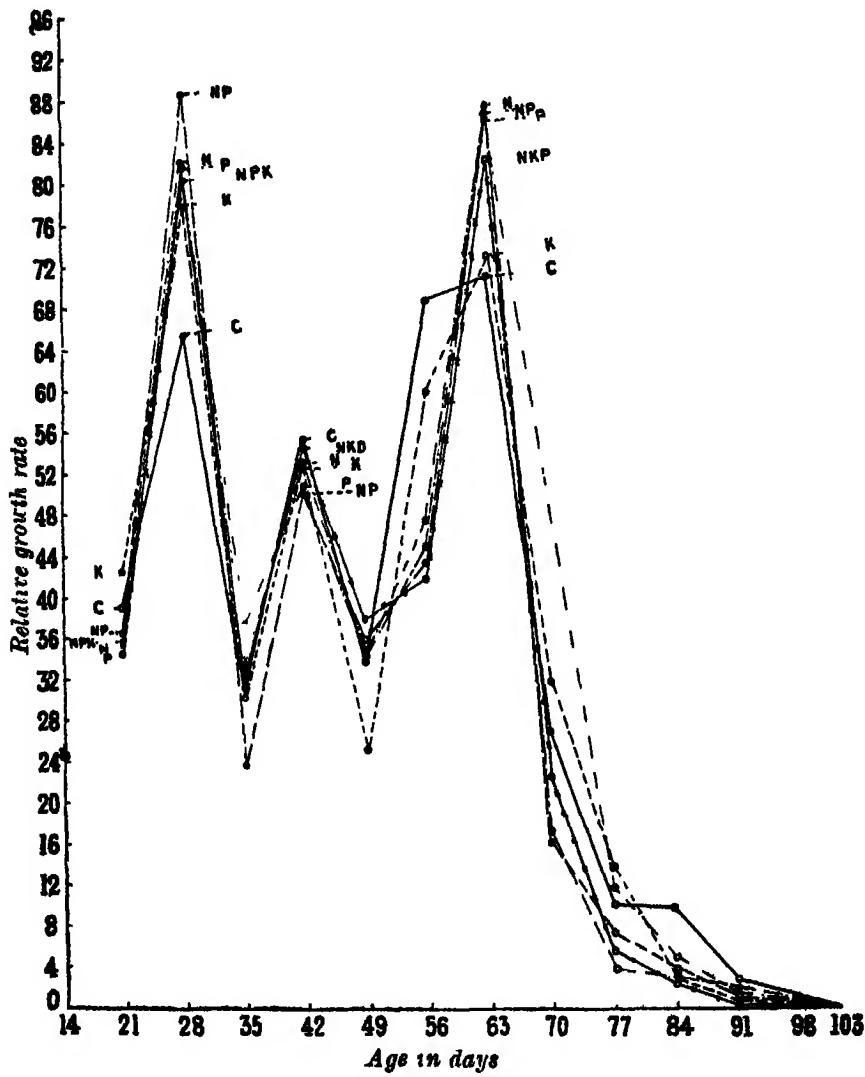


Fig. 2  
Relative growth rate of wheat under fertiliser treatments

- C ————— Control
- N - - - Ammonium sulphate
- K - - - - Potash sulphate
- NKP - - - - - Potash mixture
- NP - - - - - Ammonium phosphate
- P - - - - - Superphosphate

observed at the early vegetative phase (21–28 days), the second one at the pre-flowering period (42 days) while the final one is noticed at the flowering stage (63 days). Plants grown with the different fertilisers exhibit a marked increase in their rate of growth as compared to the control plants, specially during the vegetative and the flowering stages when the need for nutrition is most felt. A perusal of the curve further indicates that the intensity in the rate of growth seems to be partially correlated with the nature of manure added. Thus, in the seedling stage the  $N_{22}P_{22}$  (ammonium phosphate) treated plants exhibit the maximum growth rate while in the flowering stage this is shifted to  $N_{22}$  (ammonium sulphate) series. The significance of these results would be discussed in a subsequent contribution.

*Water Requirements* — When transpiration per unit dry weight is plotted against the age of the plant four characteristic phases become evident (Fig. 3). The seedling stage (14th day) is characterised by a high transpiration activity which goes on declining till a low efficiency is indicated during the pre-flowering stage (49th day). There is again a sharp rise and a high transpiration rate is observed during the flowering stage (63rd day). Soon after this, there is again a fall and the lowest transpiration rate is obtained during the senile stage. The curves of the plants for both the control and the treated series show these four characteristic phases, variations being noted in each case only in the amount of water transpired for the plants grown under different fertiliser treatments. One of the chief characteristics of the treated plants is the lower value of transpiration per unit dry weight as compared to the control plants. It is interesting to observe that the plants receiving  $K_{22}$ , (potassium sulphate) show the least amount of transpiration while NP, N, NKP and P follow the decreasing order of efficiency. This order does not remain constant since towards the latter stages of the growth, the order reverses to NP, N, NKP and K. A study of the data presented in Fig. 3 further shows that, as in the control plants, the plants of the other series also exhibit the two critical periods of water requirement which are at the seedling and the flowering stages of their life-cycle. The addition of the fertilisers therefore does not bring about any drift in the critical periods when the maximum supply of water should be available for the growth of wheat plants.

The high transpiration efficiency of differently treated plants during the very early seedling stage and the pre-flowering decline to a very low value, and the more or less similar trend of the values for evaporating power of the atmosphere (Table II) indicate that the ups and downs noted in the general contour of the curves may partially be related to the rise and fall in the

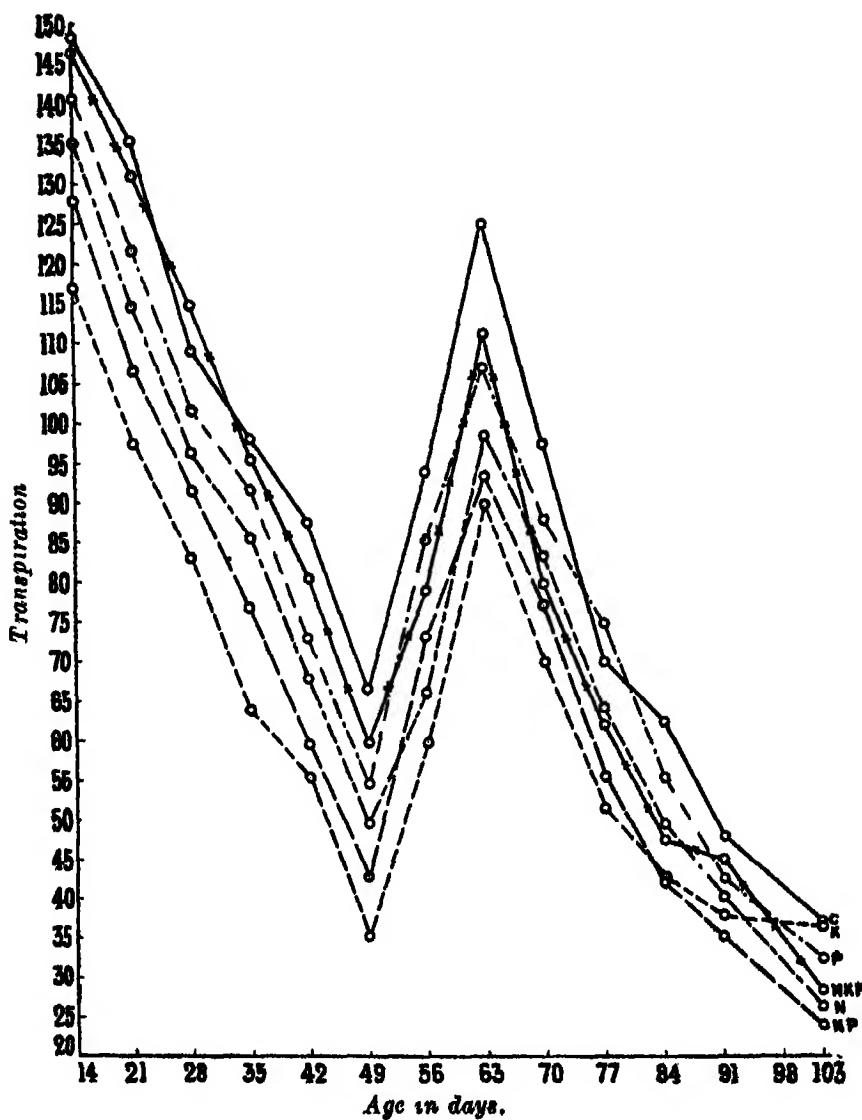


FIG. 3  
Transpiration per unit dry weight at successive life-stages  
with different fertiliser treatments

C	—	Control
N	- - -	Ammonium sulphate
NP	- - - -	Ammonium phosphate
P	- - - .	Superphosphate
K	- - - - -	Potash sulphate
NPK	- - - - - -	Potash mixture

evaporating power of atmosphere It may further be remarked that similar curves for transpiration/dry weight ratio at successive stages of growth were obtained with cotton, rice and tobacco<sup>10</sup> thus indicating that the pre-flowering decline in water requirement is a characteristic feature of majority of crop plants

An examination of the data on the total water requirement of the plants (Table III) indicates that it is considerably reduced, when the plants are

TABLE III  
*Influence of fertilisers on the water requirement of wheat*

Treatments	Average transpiration per plant, gm	Water requirement based on	
		Dry matter accumulation	Grain yield
Control	5841.91	407	1381
Ammonium phosphate ( $N_{53}P_{53}$ )	8186.92	345	960
Ammonium sulphate ( $N_{53}$ )	8808.17	386	1130
Potassium sulphate ( $K_{75}7$ )	5548	327	1010
Superphosphate ( $P_{66}$ )	7251.25	399	1200
Potash mixture ( $N_{18.5}K_{18}P_{16.15}$ )	7688.85	397	1141
Critical difference ( $P = .05$ )	163.26	11.16	519.8

manured The plants grown without any dressing of fertiliser require more water for their successful growth (unit dry matter production) than those supplied with the artificial manures A reference to the critical difference even on the 5% level of significance (Table III) shows, however, that the differences with the unmanured series are significant in all the treatments except in the cases where  $P_{66}$  (superphosphate) or  $N_{18.5}K_{18}P_{16.15}$  (potash mixture) are applied The values obtained for these two treatments are of particular interest since the effects of different treatments are clearly shown. A perusal of the data further indicates that amongst all the treatments  $K_{75}7$  (potassium sulphate) reduces the water requirement to the maximum extent. When the data of water requirements based on grain yield are reviewed a similar decrease is noted although due to a high error no significant difference is obtained The water requirement of plants both on the basis of dry matter accumulation and yield shows two distinct orders as are

put in Table IV where the value of K series (potassium sulphate) has been taken as unity for the former, while for the latter NP (ammonium phosphate) supplied this figure

TABLE IV  
*Relative efficiency of fertilisers*

Treatments	Water requirement on dry weight basis*	Treatments	Water requirement on grain yield basis†
Potassium sulphate	1 000	Ammonium phosphate	1 000
Ammonium phosphate	1 055	Potassium sulphate	1 081
Ammonium sulphate	1 180	Ammonium sulphate	1 186
Potash mixture	1 214	Potash mixture	1 188
Superphosphate	1 218	Superphosphate	1 250
Control	1 244	Control	1 438

\* Values expressed in terms of potassium sulphate taken as 1 000

† Values expressed in terms of ammonium phosphate taken as 1 000

When the question of absolute amount of water necessary for the crop after the above fertilisers are added is discussed, a computation of the primary data shows that the quantity varies from 7.4 to 9.6 acre inches (Table V) for the different series. It is indeed interesting to note that the total quantity of water necessary is slightly less when the crop is manured either by K (potassium sulphate) or P (superphosphate) alone. But when the crop is fertilised otherwise the total irrigation in acre inches is increased beyond that required for the unmanured plants by about 5-12% although such an extra expenditure is more than heavily repaid by the high increase in yield obtained in all these cases. One of the greatest advantage lies in the fact that no increase in the number of irrigation is necessitated although a slightly heavier demand of water is made. It is therefore apparent that the fertilisers may be advantageously used for obtaining higher yield at a relatively low cost of irrigation.

Thus, in addition to inducing favourable variations in morphological and other plant characteristics, the benefit of the use of the fertilisers lie in inducing drought resistivity effecting thereby an economy in the water balance of the plant system. From a purely economic point of view their application has the twofold advantage of greater yield accompanied by a lower cost of irrigation.

TABLE V

*Influence of fertilisers on the water requirement of wheat in acre inches and the yield of both straw and grains in lbs per acre*

Treatments	Total water required by crop per acre in gallons*	Total water in acre inches†	Yield per acre	
			Grain in lbs	Straw in lbs
Control	106548	8.6	1232	2944
Ammonium phosphate	204508	9.0	1855	3401
Ammonium sulphate	217802	9.6	1681	3283
Superphosphate	193438	8.5	1473	2962
Potash mixture	214151	9.4	1644	3079
Potassium sulphate	166602	7.4	1374	2917

\* These values were found out by adding the water transpired by the crop and the water evaporated from the soils in gallons per acre

† These values have been calculated on the basis of amount of water required to irrigate one acre of wheat

### Summary and Conclusions

A detailed study has been made to elucidate the after-effects of the addition of certain fertilisers, e.g., ammonium sulphate, ammonium phosphate, potassium sulphate, superphosphate and potash mixture on the growth and water requirement of wheat

Treated plants in general exhibit decided improvement in their growth than the untreated ones. While the height, tiller number and total dry matter accumulation per plant are significantly better in all the fertilised series than the unmanured ones, K<sub>78</sub> (potassium sulphate) and P<sub>68</sub> (superphosphate) applied alone do not show significantly higher increase in the yield of grain and straw as also of the length of earhead or the absolute weight of the grains

The general effect of the fertilisers is to cut short the water requirement of the treated plants to values much below that obtained for the control ones although with P<sub>68</sub> (superphosphate) and N<sub>10</sub>K<sub>15</sub>P<sub>16</sub> (potash mixture) the differences are not statistically very significant. The total amount of water necessary for raising a successful crop of wheat is therefore less in certain cases, e.g., potash sulphate and superphosphate, while in other series it increases beyond the values recorded for control apparently due to the

very high yield of grain obtained in these cases. Thus, the application of fertilisers besides showing the higher yield of the crop has the added advantage of minimising the cost of irrigation.

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# SOME ASPECTS OF THE ANATOMY OF ANURA (AMPHIBIA)—A REVIEW\*.

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\* Based on the published papers of the author and accepted for the Doctor of Science Degree of the University of Madras, March 1938.

### I Introduction

At the outset, it must be pointed out that under the title of anatomical studies of Indian and some extrapeninsular Anura, I have examined the cranium and larynx by the method of sections and also by gross study, and the morphological features of the vertebral column of some Indian anuran species by the latter method. It may be remarked here, that the study of cranial morphology by the method of sections revived at the incentive, given by Dr de Villiers of South Africa, is still young. The various internal anatomical characters exhibited by the anuran species have to be examined comparatively and then only we can embark upon any generalizations. As we go on working, the only procedure can be, therefore, to correlate and compare such features as become manifest in the several families and sub-families and then try to assess their usefulness from the view-point of taxonomy. In trying to correlate these characters, we have to bear in mind that the environmental conditions may have a profound influence upon the organization of individuals, and that secondary modifications in response to changed surroundings are often largely developed.

I have examined the cranial morphology of adult specimens of the following species and in many cases more than one specimen has been utilised for this purpose (author, 1932, 1932 a, 1934, 1935, 1935 a, 1937).

#### 1 Microhylidae

*Microhyla ornata* Dum & Bibr

*Kaloula pulchra* Gunth part (*K. pulchra taprobanica* Parker, 1934)

*Uperodon systema* Schneid (*Cacopus systema* Schneid)

*Glyphoglossus molossus* Günth

#### 2 Ranidae

*Rana hexadactyla* Less

*Rana cyanophlyctis* Schneid.

*Rana cURLipes* Jerdon

#### 3 Rhacophoridae (Polypedatidae)

*Rhacophorus maculatus* Blgr.

*Rhacophorus microtympanum* Günth

*Philautus petersi* Blgr.

*Philautus chalazodes* Günth.

*Philautus oxyrhynchus* Günth

4 *Bufonidae*

- Bufo melanostictus* Schneid  
*Bufo parietalis* Blgr  
*Bufo hololius* Gunth  
*Bufo beddomii* Gunth  
*Nectophryne misera* Mocq

5 *Pelobatidae*

- Megophrys major* Blgr (*M. gigas* Jerd = *major* Blgr)  
*Scaphiopus holbrookii* Harlan

The descriptions of the sections of the larynx of *Uperodon systema* Schneid, *Kaloula pulchra* Gunth part (*K. pulchra taprobanica* Parker) and *Microhyla ornata* Dum and Bibr (author, 1932 b) are given, and morphological accounts of the larynx of *Megophrys major* Blgr and *Scaphiopus hammondii* (author, 1935 b) and of the hyoid of these and of the South Indian Microhylid forms named above are described.

The morphology of the adult vertebral column in the following species is described (author, 1933)

1 *Rhacophoridae* (Polypedatidae)

- Rhacophorus maculatus* Blgr  
*Rh. eques* Gunth  
*Rh. microtympanum* Gunth  
*Philautus chalazodes* Gunth  
*Ph. sylvaticus* Rao †  
*Ph. nasutus* Gunth  
*Ph. oxyrhynchus* Gunth  
*Ph. sp* (marked B in the Central College Museum collection)

2. *Ranidae*

- Micrixalus saxicola* Jerd  
*Micrixalus sp* (marked A in the Museum collection)  
*Nyctibatrachus major* Blgr  
*N. pygmaeus* Blgr  
*N. sanctipalustris* Rao (1920)  
*Nannobatrachus kempholeyensis* Rao (1937)  
*Rana beddomii* Gunth  
*R. thagmandalensis* Rao (1922)

† This form has been since discovered to be a new species of *Nyctibatrachus* by Rao (1937), and is therefore treated as *Nyctibatrachus sylvaticus* Rao.

- R breviceps* Schneid
- R brevipalmata* Peters
- R crassa* Jerd. (= *R tigrina* var *crassa* Jerd)
- R cyanophlyctis* Schneid
- R curtipes* Jerd
- R diplosticta* Blgr
- R gracilis* Gravh
- R intermedius* Rao (1937)
- R leithii* Blgr
- R leptodactyla* Gunth
- R limnocharis* Wiegmann
- R malabarica* Tsch
- R pantherina* (*R tigrina* var *pantherina* Fitz)
- R parambiculamana* Rao (1937)
- R semipalmata* Blgr
- R tenuilingua* Rao (1937)
- R sauriceps* Rao (1937)

The occurrence of a Bursa angularis oris or Mundwinkeldruse is reported by me (1933 a) in *Glyphoglossus molossus* Gunth, *Uperodon systoma* Schneid, *Microhyla ornata* Dum and Bibr *Kaloula pulchra* Gunth (*K pulchra taprobanica* Parker) and in *Rhacophorus maculatus* Blgr. The Apodan genera *Ichthyophis* and *Uræotyphlus* were also investigated in this connection.

With regard to the Microhylid species investigated by me, the genus *Kaloula* Gray has been subsequently split into two, *Kaloula* Gray and *Ramanella* Rao by Parker (1934) and this splitting is based on the difference in the nature of the prevomer. Rao (1925) described a new genus of Microhylid frog from South India which he called *Ramanella symbiotica* and he makes no reference to the exact nature of the prevomer in this species. This form, however, was later discovered to be none other than a species of *Kaloula*, *K variegata* Stoliczka. But Parker (1934) retains the generic name *Ramanella* for accommodating five species which were originally included under *Kaloula* Gray and according to him the difference between *Kaloula* Gray and *Ramanella* Rao is that in the latter, the prevomer is reduced and broken up. My descriptions of *K pulchra* were drawn up from a specimen of the race which Parker subsequently described as *K pulchra taprobanica* (1934).

As regards the other genera, I included *Rhacophorus* (*Polypedates*) under the family Ranidae following the observations of Gadow (1901) and

Boulenger (1882 and 1890) But Noble (1927 and 1931) has dissociated *Rhacophorus* from the Ranidæ and erected a new family Polypedatidæ, in which he includes *Rhacophorus* (*Polypedates*), *Philautus* and some other genera. Moreover, the genus *Rana* itself has been split into nine subgenera by Boulenger (1920), viz., *Rana*, *Iomopterna*, *Hildebrandtia*, *Ptychadenia*, *Aubria*, *Hylorana*, *Discocleis*, *Nanorana* and *Pyxicephalus*. The two species *R. hexadactyla* and *R. cyanophlyctis* come under the subgenus *Rana* s. str., while *R. curtipes* is included under the subgenus *Hylarana*. This splitting is very well supported by my anatomical observations.

In describing the Bufonid head (author, 1937), I have remarked in the introduction that *Noladen* is a member of the family Bufonidæ. I have followed Gadow (1901) and Noble (1931) in this, and Noble (1931) correctly points out that neither *Noladen* nor *Myobatrachus* shows any "affinity to bufonids found to-day outside Australia" and insists that they do not belong to the subfamily Bufoninae which according to Parker (in litt.) is approximately equal to Bufonidæ of Gadow and Boulenger. With regard to the other genus *Nectes*, it was placed as a synonym of *Pseudobufo* by van Kampen (1923) and this nomenclature is followed by Smith (1930). Further the Bufonid genus *Cophophryne* of Boulenger is treated by Noble (1931) under the family Pelobatidæ.

In connection with the vertebral column, I have examined members belonging to the two families Ranidæ and Rhacophoridae (Polypedatidæ). Subsequent to the publication of a note on the proœalous nature of the 8th and 9th vertebrae in *Rhacophorus maximus* by Mookerjee (1932), it occurred to me that "if it could be shown that the vertebrae are uniformly proœalous in this genus *Rhacophorus*, then its inclusion under the family Ranidæ, becomes a questionable procedure". I have examined four species of *Rhacophorus* of which one (*R. maculatus*) confirms the observations of Nicholls (1915–16) in being diplasiocœlous.

## II Literature Selected

In referring to previous work I have largely restricted myself to recent workers who have studied the skull of anuran species by the method of sections. This does not necessarily mean that I have ignored the morphological descriptions of other authors, and in some cases I have not been able to secure the necessary literature, and therefore, my bibliographical list may not be exhaustive.

## III Review

(a) *Narial region*—The very first structure that we meet with in the rostral end of the anuran examples studied is the prenasal cartilage

associated with the premaxilla. In the Microhylid examples studied, it is noticed that *Uperodon* and *Glyphoglossus* possess both the prenasal cartilages (prenasalis superior and inferior) while their congeners *Microhyla ornata* and *Kaloula pulchra* (*K p taprobanica*) possess only the superior cartilage. On p 2 of my paper on the *Glyphoglossus* head (author, 1932 a) I have said, "At the outset it must be pointed out that *Glyphoglossus* stands apart from the other members of the group Engystomatidae in very many features. Both the prenasal cartilages, the superior and inferior, are present and support the premaxillæ". This gives an idea that the Microhylid (Engystomatid) examples examined possess only one prenasal cartilage, the sentence ought to read "*Glyphoglossus* possesses both the prenasal cartilages and in this feature it resembles *Cacopus*, but in many other characters it differs from the other members of the same family with which it has been compared". In the Ranid forms (*R hexadactyla*, *R cyanophlyctis*, *R curtipes*) and the Rhacophoridae (Polypedatidae), (*Rh maculatus* and *R microtympanum*, *Philautus petersi*, *P chalazodes*, *P oxyrhynchus*) and the Bufonid examples (*B melanostictus*, *B parietalis*, *B hololius*, *B beddomii* and *Nectophryne misera*) both the prenasal cartilages are present.

*Previous work*—In the forms examined by de Villiers (*Phrynomerus* 1930 a, *Cacosternum* 1931, *Anhydrophryne* 1931 c, *Asaphus* 1934, *Rhombocephryne* 1934 a, *Microbatrachella* 1934 b) the prenasal cartilages are double, while in *Breviceps fuscus* (1931 d), the superior is reduced, in *Hemisus* (1931 b), the inferior is absent. In *Bufo* (Schoonees, 1930), *Phrynobatrachus* (G du Toit, 1933), *Liopelma* (Wagner, 1934), *Rana* and *Crinia* (C du Toit, 1933, 1934) and *Spelaeophryne* (de Vos, 1935) the prenasal cartilages are normally disposed.

The cartilaginous tectum of the nasal capsule gives rise anteriorly to the *cartilago alaris* and *cartilago obliqua*. The alary cartilage gives attachment to the superior prenasal cartilage, while from the *cartilago obliqua*, depends into the nasal chamber, a plica. In *Rana* the plica (Bruner, 1902) is described as a connective tissue projection into the nasal chamber depending from the tectal cartilage. But in the forms examined by me (Microhylidae, viz., *Uperodon systema*, *K pulchra* (*K p taprobanica*) and *Microhyla ornata* (1932), *Glyphoglossus molossus* (1932 a), Ranidae (1935), Pelobatidae (1935 a) and Bufonidae (1937), the plica depends from the *cartilago obliqua* and not from the tectum. In Rhacophoridae (Polypedatidae) (author, 1934) the plica may depend from the tectum (examined species of *Philautus*) or from the *cartilago obliqua* (*Rhacophorus maculatus* and *R microtympanum*).

**Previous work**—According to de Villiers the oblique suspension is noticed in *Phrynomerus* (1930 a), *Cacosternum* (1931), *Anhydrophryne* (1931c), *Rhombophryne* (1934 a), *Microbatrachella* (1934 b), and by C du Toit in *Rana grayi* (1933). Similarly in *Phrynobatrachus* (G du Toit, 1933), *Bufo* (Schoonees 1930) and *Spelæophryne* (de Vos, 1935). However in *Liopelmidæ* (Wagner, 1934), *Crinia* (C du Toit, 1934) and *Breviceps fuscus* (de Villiers, 1931 d), the plica depends from the tectum.

The nasal chamber referred to above is disposed in the form of three sacs—the cavum principale, cavum medium and cavum inferius. It is noticed that posteriorly, the cavum principale opens into the buccal cavity by means of the choana. The cavum medium gives rise to the ductus nasolacrimalis on its external aspect which opens below the eye normally by a single opening. In *Scaphiopus holbrookii*, the cavum medium is comparatively diminished in size. The cavum inferius, it may be noted in passing, is differentiated into a recessus medialis towards the septum where it is surrounded by glands in all the forms examined. Now, this recessus medialis is considered to represent the Organ of Jacobson so commonly met with in Reptiles and other examples. Lapage (1928) homologises the cavum inferius with the Organ of Jacobson and Howes (1891) is inclined to believe that the supposed Organ of Jacobson in Amphibia is a maxillary sinus. Gaupp, however, notes the recessus medialis as Jacobson's Organ. I have followed the descriptions of Gaupp and labelled the thickened internal part of the cavum inferius as recessus medialis.

(b) **Prechoanal sac**—Another important feature one meets with in the sectional views of the narial region of *Uperodon systoma*, *Microhyla ornata* and *Kaloula pulchra* (*K. p. taprobanica*) is the occurrence of a prechoanal sac. In *Uperodon systoma* anterior to the choanal opening, there appears a vestigial sac in the roof of the mouth—the prechoanal sac. In *M. ornata* and *K. pulchra* (*K. p. taprobanica*) the cavum principale opens on either side into a prechoanal sac and these two sacs open into the buccal cavity. However, in the larval forms of one of these examples (*M. ornata*) no prechoanal sac is noticed, though in the case of *U. systoma*, the choanæ of the tadpole enter into a spacious prechoanal sac which opens into the buccal cavity posteriorly. I have not examined the larval forms of *Kaloula* since I was not able to secure the tadpoles. Now, with regard to the morphological significance of the prechoanal sac found in the adult of *M. ornata* or *K. pulchra* (*K. p. taprobanica*), I noticed that a similar state of affairs is met with in *Phrynomerus* (de Villiers, 1930 a). He notes that "it is

more than probable that the sacs referred to above are vestiges of the Organ of Jacobson". Then if this view is accepted, is it that the narial part of the Jacobson's Organ is represented by the recessus medialis of the cavum inferius and the buccal division in *Microhyla* and *Kaloula* by the prechoanal sacs? In the other examples investigated by me, a prechoanal sac is absent from *Glaphoglossus* (author, 1932 a), *Rhacophorus microtympanum*, *Philautus petersi*, *P. chalazodes*, *P. oxyrhynchus* (author, 1934), *Rana hexadactyla*, *R. cyanophlyctis*, *R. curtipes* (author, 1935), *Scaphiopus holbrookii* (author, 1935 a), *Bufo parietalis*, *B. hololius*, *B. beddomii*, *Nectophryne misera* (author, 1937) while in *Rhacophorus maculatus* (author, 1934) and *Megophrys major* (author, 1935 a), it is present.

*Previous work*—I will only refer to those forms where a prechoanal sac is noticed. *Phrynomerus* (de Villiers, 1930 a) has a paired prechoanal sac. *Cacosternum* (de Villiers, 1931 a) has an unpaired one, similarly in *Breviceps* and *Probreviceps* (de Villiers, 1932 a), *Hemisus* (de Villiers, 1931 b), *Spelæophryne* (de Vos, 1935) and *Rana grayi* (C du Toit, 1933).

(c) *Septomaxilla*—Associated with the narial cartilages, viz., lamina superior crista intermedia and lamina inferior crista intermedia, the septomaxilla (internasal of Gaupp) makes its appearance. This bone, possessing posteriorly divaricula or limbs, is noticed to embrace the recessus sacciformis or the infundibulum (the passage between the cavum principale and cavum medium). In the case of *Rana* (author, 1935) the posterior portion of the septomaxilla is triradiate, this arrangement is not seen in the case of *Scaphiopus holbrookii* (author, 1935 a). It is noticed in the latter example that after the fusion of the two limbs (the superior laminar and inferior laminar) of the septomaxilla as in *Rana*, the bone again appears as two investments of the planum and continues to be so till it finally disappears, thus differing from the Ranid type where the bone is noticed to delimit the anterior extremity of the planum. Now, in the Bufonidae (author, 1937) the bone follows the common plan in the examined species of *Bufo* while in *Nectophryne misera* the disposition is slightly different. At any rate, there is a common feature between the two genera, a limb of the bone appears below the plica in *Bufo* and slightly behind the plica in *Nectophryne misera*—a feature not met with in the Ranidae and Rhacophoridae (Polypedatidae). In the latter family (author, 1934) the arrangement of the bone is Ranid in nature. The minor variations noticed are not of great significance but it is to be noted, however, that the nature of the bone itself has been interpreted in two ways. According to Lapage (1928) the bone is considered as "originally a cartilage

bone" and one of the criteria in determining this is "in certain places for example, where the septomaxillary is in contact with the lamina superior of the crista intermedia, these cartilages seem to be continuous with the septomaxillary—a fact which further supports the view that the septomaxillary arises in the cartilage" (p 413) Now in the case of the examples studied by me, in certain regions of the laminar cartilage of *Uperodon systoma*, *Kaloula pulchra* (*K p taprobanica*) and *Microhyla ornata*, the bone is actually in contact with the cartilage thereby supporting Lapage's theory This, in fact, is really very pronounced in *K pulchra* (*K p taprobanica*) I, therefore, concluded at the time that in these examples the bone was of cartilaginous origin which, of course, was not supported by embryological evidence Subsequent study has convinced me that in a large majority of forms like *Rana*, *Rhacophorus* (*Polypedates*), *Philautus*, *Bufo*, *Nectophryne*, *Megophrys* and *Scaphiopus*, the bone is separated from the cartilage by connective tissue, and, more than that, "the attachment and apparent continuity of one end of the bone with that part of the cartilage of the nasal capsule does not mean that the bone was preformed in cartilage" (de Beer, 1937) A study of the development of the bone will finally settle the matter and till then it may be treated as a membrane bone

*Previous work*—W K Parker (1881) describes a large number of forms without a septomaxilla, and it has been shown that his observations are inaccurate in some cases De Villiers and his school describe it as a membrane bone

(d) *Eminentia olfactoria*—Both anteriorly and posteriorly to the choana, the solum may give rise to an elevated cartilage into the cavum principale which is called the eminentia olfactoria Such an elevation is remarkably well developed in the fossorial *Uperodon systoma*, *Microhyla ornata* and *Kaloula pulchra* (*K p taprobanica*) *Uperodon* is found to live several feet below the earth, while *Microhyla* lives under loose sand and *Kaloula* under rocks and the bark of trees Further, in the case of *Scaphiopus holbrookii* (author, 1935 a), *Bufo* (author, 1937), *Glyphoglossus* (author, 1932 a), *Rana hexadactyla* and *R cyanophlyctis* and (author, 1935), the eminentia is elevated In the other examples investigated, viz., *Rhacophorus* (*Polypedates*), *Philautus*, *Rana curtipes*, *Megophrys major* and the arboreal *Nectophryne misera*, the eminentia is flat and not elevated The African School of anatomists headed by de Villiers put forward a theory that the elevation of the eminentia is closely correlated with the fossorial mode of existence of these animals De Villiers (1932 a) significantly remarks in this connection that ".increase in the area of the eminentia olfactoria

represents a purely physiological phenomenon, associated with adaptation to terrestrial life and has been independently evolved in Bufonidae, Ranidae and Brevicipitidae". This view fitted in extremely well when I worked out the Microhylid examples but when I investigated the Ranid forms like *R. hexadactyla* and *R. cyanophlyctis* and *R. curtipes*, I was rather struck by the variation noticed in the nature of the eminentia. It is elevated in *R. hexadactyla* and *R. cyanophlyctis* while in *R. curtipes* it is flat. It is very well known that the former two examples are completely aquatic forms, and therefore, the occurrence of an elevated eminentia does not very well fit in with the theory that the elevated eminentia is closely correlated with a fossorial mode of existence even though it may have been evolved independently. If the two Ranid genera were terrestrial, the independent evolution of the elevated eminentia would have amply borne out but since they are aquatic, I pointed out (1935, p 6) that "the elevation of the eminentia has probably nothing to do with terrestrial adaptations of the Anura. It may, however, be said that the structure increases in area purely in response to the sensory requirements of the individual". Probably experimental zoology may be able to clear this difficulty.

*Previous work* — The occurrence of an elevated eminentia is noticed in *Phrynomerus* (de Villiers, 1930 a), *Breviceps* (de Villiers, 1931 d), *Pro-breviceps* (de Villiers, 1932 a) and *Spelæophryne* (de Vos, 1935) and no reference is made to it in *Rhombophryne* (de Villiers, 1934 a). In *Bufo angusticeps*, Schoonees (1930) records an elevated eminentia.

(e) *The sphenethmoid bone (Os en Ceinture Cuvier)* — This bone occurring in the ethmoid region is known as the girdle-shaped bone since it forms a girdle round the brain. It appears in the anterior sections on the lateral aspects of the brain and posteriorly extends ventrally also and in some examples a piece of trabecular cartilage is left unossified midventrally, when the bone is said to be distinctly paired. Such a feature is noticed in *Uperodon systema*, *Microhyla ornata*, *Kaloula pulchra* (*K. p. taprobanica*), *Rh. microtympanum* and *Philautus chalazodes*. In the last two species the sphenethmoid is feebly developed. However, in *Rana hexadactyla*, *R. cyanophlyctis*, *Megophrys major*, *Scaphiopus holbrookii*, *Philautus oxyrhynchus* and *P. petersi*, there is no ventral trabecular piece and the bone is one complete girdle. In *P. petersi* the bone originates far anteriorly in the septum nasi. In *Rhacophorus microtympanum* a feeble sphenethmoid is seen and in *Rana curtipes* in the sphenethmoid region, no ossification is noticed.

(f) *Subethmoidal cartilage* — There is a remarkable feature noticed in the case of *Rana cyanophlyctis* in the ethmoid region. In the anterior region of

the sphenethmoid, disposed between it and the parasphenoid, is a cartilage which has been called the subethmoidal cartilage, also noticed in *Rana grayi* (C du Toit, 1933) What exactly is the significance of this cartilage, I am unable to say

*Previous work*—W K Parker's monograph (1881) on the Anuran skulls gives us an account of the sphenethmoid but unfortunately the double nature is not disclosed in many forms The paired nature of the bone is described by de Villiers in *Phrynomerus* (1930 a), *Rhomboophryne* (1934 a), by C du Toit in *Crima* (1934), by G du Toit and de Villiers in *Hyperolius* (1932), by Wagner in *Liopelma* (1934) In the other forms whose cranial anatomy has been studied variations are met with In *Cacosternum*, the sphenethmoid is noticed posteriorly (de Villiers, 1931, 1931 a), the bone is completely girdle-shaped in *Phrynobatrachus* (G du Toit, 1933) and in *Rana grayi* (C du Toit, 1933) and in *Bufo angusticeps* (Schoonees, 1930) portions of cartilage are discovered in the bone In *Breviceps* and *Pro-breviceps* (de Villiers, 1932 a) and in *Spelæophryne* (de Vos, 1935), the bone is wanting In *Ascaphus* (de Villiers, 1934) an orbitosphenoid is described and in 'Liopelmidæ' Wagner (1934) describes the sphenethmoid as paired Peculiarly in *Hemisus* (de Villiers, 1931 b) the bone has fused with the nasals above Representatives of 58 genera have been examined by Parker (1934) and the normal condition in these is that the sphenethmoid is single, however, variations in few cases were also met with

(g) *Maxillæ*—The premaxillæ and maxillæ do not show many variations However, it may be remarked that in the Microhylid species examined by me, viz., *U. systema*, *M. ornata* and *K. pulchra* (*K. p. taprobanica*), the maxillæ (and also the prevomers) are edentulous Now it has been long established that no stress need be laid on the dentigerous or edentulous nature of the bones, for in the same family, members possessing teeth (e.g., Microhylid Dyscophinæ) and also without them are found Again in *Bufo* and *Nectophryne* (author, 1937) the maxillæ and prevomers are edentulous while in *Ranidæ* (the author 1935) and *Rhacophoridae* (Polypedatidæ) (author, 1934), the maxillæ are dentigerous Therefore, this character cannot be utilised for systematic purposes especially with reference to the Microhylid family

*Previous work*—W K Parker (1881) describes a large number of forms with and without teeth on the maxillæ In describing the maxillary bones, de Villiers (1931) also notes that "Noble has repeatedly

maintained that no great systematic value can be attached to the absence or presence of teeth" In describing the cranial morphology of *Cacosternum* (1931, 1931 a) he notes that the species of this genus behave rather differently, *C. bottigeri* and *C. capense* possess premaxillary teeth while *C. namaquense* does not but the maxillæ are dentigerous Peculiarly, the Microhylid genera, *Breviceps* and *Pro-breviceps* (de Villiers, 1932 a), *Rhombophryne* (de Villiers, 1934 a) and *Spelaeophryne* (de Vos, 1935) possess edentulous maxillæ *Phrynomerus* (de Villiers, 1930 a) which is treated as a genus under the family Phrynomeridae by Parker (1934) also possesses, like the Microhylid genera referred to above, edentulous maxillæ

(h) *Prevomer* (Broom) —The topographical disposition and the nature of this bone is largely used in Anuran taxonomy In the species that I have examined of the Microhylid family, viz., *U. systoma*, *M. ornata*, *K. pulchra* (*K. p. taprobanica*) and *Glyphoglossus molossus*, the disposition of the prevomer is based on a common plan In *U. systoma*, the prevomer appears divided anterior to the choana, is edentulous and there is a small bone posterior to the choana, which I have called the degenerate palatine in consonance with the nomenclature adopted in labelling the bone occurring in this region in other anuran genera on purely topographical evidence In the second species of *Uperodon*, *U. globulosum*, the prevomer embraces the choana (Parker, 1934) and a palatine is wanting Now, since the palatine is absent in this species, it is thought that in other species *U. systoma* also, a true palatine is absent and the degenerate bone that is present postchoanally [palatine according to me (1932) and Devanesan (1922)] may be the posterior portion of the prevomer If, however, it is proved that *U. systoma* is more primitive and possesses a prechoanal prevomer and a degenerate palatine, then the condition noticed in *U. globulosum* should be interpreted as one in which a fused prevomeropalatine bone is noticed My slides of the head of *U. systoma* do not provide any clue to this problem In *K. pulchra* (*K. p. taprobanica*) the prevomer is large and edentulous and in the alizarin preparations that I have examined of *K. pulchra* (*K. p. taprobanica*), the prevomer is well developed and the postchoanal portion is associated with the well-developed palatine I have already remarked that according to Parker (1934), the genus *Kaloula* Gray is split into two genera *Kaloula* Gray and *Ramanella* Rao, based on the nature of the prevomer, and since I have not described any species belonging to *Ramanella* in these two papers (author, 1932, 1932 a), I shall not discuss the prevomerine condition in the latter genus On p 11 of my paper (author, 1932), I have said that "The

vomer does not form a vomeropalatine and in *Kaloula* the vomer is superimposed by the palatine." It ought to read that the palatine is superimposed by the vomer. Now in *M. ornata*, the prevomer is poorly developed and a limb of it extends intrachoanally as in *Phrynomerus* (de Villiers, 1930a) but this does not embrace the choana posteriorly. I have clearly stated this point in my paper on Rhacophoridae (Polypedatidae) (author, 1934, p. 84). "The occurrence of this intranasal prolongation of the vomer (prevomer) is also noticed in one of the South Indian Engystomatid examples *Microhyla* and in a large number of foreign forms [see *Phrynobatrachus* (G. du Toit, 1933) and *Phrynomerus* (de Villiers, 1930)]". In my specimen of *Glyphoglossus molossus* (author, 1932), the prevomer is small and there is no intrachoanal prolongation as much as we see in *M. ornata*. But in a figure drawn by Parker (1934, p. 72) of the ventral aspect of the cranium of *G. molossus*, a prevomer which embraces the choana is shown. I am unable to make out the palatine as an independent bone in the figure and in the description we read "Prevomer undivided, the postchoanal portion overlying the palatine region and bearing, mesially, one or two knob-like prominences (Fig. 30)." The figure suggests that a prevomeropalatine arrangement is present. My description of the prevomer in *Glyphoglossus* (author, 1932a) is that "at the base of the solum nasi the prevomer makes its appearance and unlike the Brevicipitidae and *Microhyla*, no extension of the prevomer seems to embrace the choanae in *Glyphoglossus*". What I mean by "embrace" is an intranasal prolongation of the prevomer as in *Microhyla*, and not a post-choanal extension as seen in *U. globulosum*. As already noted above, I have made this point clear in my paper on Rhacophoridae (Polypedatidae) (author, 1934, p. 81, *vide supra*). Further my slides do not disclose 'the postchoanal portion overlying the palatine region' in *Glyphoglossus* as described by Parker (1934, p. 72). This is due to the fact that my observations were made on an immature specimen. In this, the bone investing the ventral aspect of the antorbital cartilage which I called the palatine is separate, and there is a prechoanal prevomer. When the adult condition is reached, the prevomer and the palatine (if it is a palatine) obviously fuse together (Parker in litt.) and a prevomeropalatine arrangement is noticed, or it may be that the palatine really represents the postchoanal portion of the prevomer. Then, the figure drawn by Parker (1934, p. 72), represents a prevomer with a postchoanal portion or it may be a prevomeropalatine bone. Further, Parker points out that this genus *Glyphoglossus* "ought, perhaps, to be united with *Uperodon*. *Uperodon globulosum* is almost exactly intermediate between the type species of *Uperodon* and *Glyphoglossus*." In adult *U. systema*, then, there is a pre-

choanal prevomer and a postchoanal prevomer or palatine, in *G. molossus*, the juvenile specimens show a prevomer and a postchoanal prevomer or palatine and in the adult, the prechoanal and postchoanal portions fuse representing either a prevomer or a prevomeropalatine. Similarly in *U. globulosum*, the bone may be a prevomeropalatine or a true prevomer with a postchoanal limb. Now, in the Rhacophorid (Polypedatid) family examined (author, 1934), the prevomer is rather interesting. According to Boulenger (1890), the difference between *Rhacophorus (Polypedates)* and *Philautus (Iaalus)* consists in the presence of vomerine teeth in the former and their absence from the latter. I have noted in that paper (author, 1934, p. 82) that "This may not be so very safe and stable criterion of enough systematic importance since Boulenger himself is doubtful about the existence of vomerine teeth in *Rhacophorus dubius*". Noble (1927, 1931) at any rate, distinguishes *Rhacophorus (Polypedates)* from *Philautus* by the absence of vomerine teeth in the latter and he points out that the genus is derived from *Rhacophorus* by a 'loss of the vomerine teeth'. However this may be, the family Rhacophoridae (Polypedatidae) according to the same author (1931), is a natural group possessing cylindrical sacral diapophyses, intercalary cartilages and a diplasiocelous vertebral column, and further confirms his statement by saying that "the anatomical evidence at present available points toward the Polypedatidae as being a natural group" (p. 525). Within the family, since *Philautus* has arisen from *Polypedates* by the loss of vomerine teeth, Noble is inclined to believe that *Philautus* is not a natural genus but a polyphyletic one. The sectional views of the prevomer reveal that the bone is dentigerous in *Rhacophorus maculatus*, *Philautus chalazodes* and *P. oxyrhynchus* while in *P. petersi* and *Rhacophorus microtympanum*, it is edentulous. Thus, both among *Rhacophorus* and *Philautus*, there are species with and without vomerine teeth and it becomes apparent how futile it is to utilise this character for purposes of further classification of these two genera. If we accept Noble's dictum that the genus *Philautus* represents a polyphyletic assemblage, then we are not justified in retaining it as a single distinct genus, we may have to merge the several species of *Philautus* under those of *Rhacophorus*. This view is very well supported by my observation of the vomerine teeth for, both genera *Rhacophorus* and *Philautus* possess species with and without vomerine teeth. But the other aspects of cranial anatomy as reported by me (author, 1934) do not warrant this, and therefore, it is very unlikely that *Philautus* is, as Noble thinks, polyphyletic, unless it be that the other characters, too, have been developed independently on more than one occasion (Parker in litt.). In the Ranid examples studied, viz., *R. hexadactyla*, *R. cyanophlyctis* and

*R. curtipes*, the prevomer is normally disposed with no postchoanal portion, is dentigerous and resembles that in *R. temporaria* (Gaupp, 1904). In the Pelobatid examples studied *Megophrys major* and *Scaphiopus holbrookii* (author, 1935 a), the prevomer is single on either side and possesses two limbs posteriorly. In *M. major* (author, 1935, p 72, Fig 5) "on the ventral aspect of the eminentia the prevomer is noticed and posteriorly, it is divided into two between which the Rachendruse are present (Fig 5 a) and more posteriorly the internal limb (Fig 5 b) is present and this is the intrachaoanal portion of the prevomer," which, however, disappears posteriorly. In *S. holbrookii*, 'Disposed at the tip of the bony eminentia is the large vomerine bone' (p 72) "The vomer (prevomer) (Figs 4 and 6 v) in *Scaphiopus* underlies the large bony eminentia and, as in *Megophrys*, in posterior regions the bone is present in the form of two parts with loose connective tissue and the Rachendruse in between" (pp 73 and 74). Posteriorly, the maxillary limb of the prevomer alone persists and this also disappears after cutting through some or more sections posteriorly. In *Bufo* and *Nectophryne misera* (author, 1937), the prevomer is small and edentulous. It does not extend postchoanally. In my introductory chapter on the Morphology of the Bufonid head, I have remarked about 'the absence of the teeth from the jaws (except Notaden)' and this implies that *Notaden* possesses dentigerous jaws. The implication was not intended, *Notaden* also lacks teeth in the jaws, but prevomerine teeth are present. In passing, it may be noted that the systematic position of *Notaden* is changed now, and I am not in possession of the literature referring to it (see, however, Noble, 1931, p 498).

*Previous work*—W K Parker (1881) depicts the prevomer in a large number of forms and he draws figures of the skulls of two species of *Microhyla* under the name of *Diplopelma* and also that of *Callula pulchra*. H W Parker (1934) describes, amongst other Microhylidae, the disposition of this investing bone in *Uperodon*, *Kaloula*, *Ramanella*, *Microhyla* and *Glyphoglossus*. In *Uperodon*, 'Prevomer entire or divided (Fig 31 and 32), the postchoanal portion overlying the palatine region and sometimes bearing a raised knob at its mesial end', in *Kaloula* 'prevomer undivided, the postchoanal portion overlying the palatine region and raised into a strong, sometimes crenulate ridge (Fig 33)'. However, Smith (1930) draws a palatal aspect of *K. pulchra* (Fig 10, p 121) and in the description he says 'vomer forming a sharp transverse ridge behind the choana, palatine much reduced, its inner extremity underlying the vomer'. In *Phrynomerus* (de Villiers, 1930 a), a vomeropalatine arrangement is

seen, in *Cacosternum* (de Villiers, 1931 a), vomer is edentulous and large, in *Breviceps* (de Villiers, 1931 d), there is an intranasal prolongation which is absent from *Probreviceps* (de Villiers, 1932 a), in *Hemisus* (de Villiers, 1931 b), the vomer is absent, in *Rhombophryne* (Noble and Parker, 1926, de Villiers, 1934 a), it is disposed in two parts, in *Ascaphus* (de Villiers, 1934), there is a toothed prevomer with the rostral portion edentulous, in *Spelaeophryne* (Parker, 1934, de Vos, 1935), the prevomer is edentulous, in *Crinia* (C du Toit, 1934), a divided prevomer is present, in *R. grayi* (C du Toit, 1933), it is simple and undivided, in *Phrynobatrachus* (G du Toit, 1933), the edentulous prevomer fringes the choana and in *Bufo* (Schoonees, 1930), the bone is edentulous. Also in *Hyperolius* (G du Toit and de Villiers, 1932) the vomer is without teeth.

(i) *Palatine bone*—In the Anura, the palatine bone shows considerable variation. Forms with and without, or with degenerate palatine or with a prevomeropalatine are not uncommon. Among the forms studied by me, in the Microhylid genera, 'the palatine observes a sequence in reduction'. *Kaloula* has a comparatively well-developed palatine, *Uperodon systema* a vestigial one (see below) while *M. ornata* has lost it. Smith (1930) remarks that in the case of *K. pulchra* (*K. p. taprobanica*), there is a 'reduced palatine' and when we compare this with the other two South Indian Microhylid examples, it must be said that the palatine is comparatively well developed. In the case of *U. systema*, a bone on the ventral aspect of the quadratoethmoidal commissure has been labelled by Devanesan (1922) as palatine and I have also followed the same nomenclature. Whether it is a true palatine or only a postchoanal portion of the prevomer is rather difficult to say and the probabilities have been discussed on pp 53–54. With regard to *Microhyla*, I have noted that the palatine is absent (author, 1932, p 11) and that 'Parker (23) finds that among the species of *Microhyla* an orthogenetic series could be established, ranging from forms having a palatine to forms completely devoid of it'. As early as 1881, W K Parker figured two species of *Microhyla* under the name of *Diplopelma* where he has drawn a well-developed palatine. Obviously, the genus contains species both with and without a palatine bone. H W. Parker (1928) as stated above, had studied all the species of the genus *Microhyla* and had come to the same conclusion. He draws an interesting correlation when he says that 'only rarely does it persist when the postchoanal portion of the prevomer is absent'. In the Ranid and Rhaeophorid (Polypedatid) forms examined (author, 1934, 1935), the palatine is normally disposed on the ventral aspect of the antorbital cartilage.

In *Megophrys major* a single specimen of which I secured from the Indian Museum at the time I reported, I have noted (author, 1935 a) that the palatine is absent and investing the ventral aspect of the quadrato-ethmoidal commissure is a projection of the maxilla. This projection forms the posterior boundary of the choana. However, after examining a large number of species of *Megophrys*, including *M. major*, Parker informs me (in litt.) that a palatine is normally present and therefore, my specimen does not represent the normal condition. Subsequently I examined another specimen of *M. major* and also discovered the same feature noticed in the first one with regard to the palatine. Mr H W Parker of the British Museum has examined my second specimen. It is to be noted that the bony extension of the maxilla described by me (author, 1935 a) as forming the posterior boundary of the choana which I propose to call maxillo-palatine, is topographically identical with the palatine of other Anura and therefore, Parker (in litt.) is inclined to label this merely as palatine bone. Further he states that if it is to be regarded as a maxillo-palatine, one of the two assumptions have to be made, viz., that it is a bone not foreshadowed in any frog and appears for the first time here or that the processus frontalis of the maxilla has grown ventrally to the antorbital cartilage. If, however, following Parker, it is labelled as palatine, the union of the maxilla and palatine in this region is lost sight of and probably this is the first anuran where such a condition of fusion has appeared.

In *S. holbrookii*, the palatine is wanting. Further, in the same paper (1935 a, p 75) it is noted that 'in all the examined species of *Microhyla* (H W Parker, 1928) the palatine is wanting.' This is not correct, and therefore, it should be re-stated that in the examined species of *Microhyla*, the palatine may be present or absent. In *Bufo* (author, 1937), the palatine is normally disposed while in *Nectophryne misera*, the bone is wanting. On p 1163, I have noted in my paper on the morphology of the Bufonid Head (1937) that 'Peculiarly, however, in the arboreal *Nectophryne*, the palatines are wanting.' This, I am informed, gives an impression that in all the species of the genus *Nectophryne*, the palatine is wanting which of course is not what I mean, my idea is that in the examined species of *Nectophryne*, the bone is wanting, which I have clearly pointed out in the summary of that paper.

*Previous work*—W K Parker (1881) draws the disposition of the palatine in a large number of forms described by him like *Callula pulchra* and two species of *Microhyla*, which he describes under the name of *Diplopelma*, *D. ornatum vel rubrum* and *D. Berdmorei* (?).

The description of Parker of these two species are as follows "In *D. ornatum vel rubrum*, the lateral rudiments of the girdle bone are less and run into their own also partially, yet an endosteal deposit, with scarcely any perichondrial bone (ectosteal palatine) runs up to the cheek." He further mentions the presence of a postpalatine being separated from the pterygoid. In *D. Berdmorei*, the palatine is feebly developed. There is no girdle bone and in both species Parker has figured a prevomer. I have not been able to secure H W Parker's paper (1931) where an account of the prevomer and palatine of *Uperodon* is given. The same author (1934) also describes the palatal bones in a large number of Microhylidae. In *Phrynomerus* (de Villiers, 1930 a), a prevomeropalatine is formed, similarly in *Liopelma* (Wagner, 1934), in *Cacosternum* (de Villiers, 1931), *Crinia* (C du Toit, 1934) and *R. grayi* (C du Toit, 1933), *Bufo* (Schoonees, 1930), the bone is normal. In *Hemisus* (de Villiers, 1931 b), *Breviceps* and *Probreviceps* (1932 a), *Ascaphus* (de Villiers, 1934) and *Spelaeophryne* (de Vos, 1935), a palatine is wanting. In *Rhombo-phryne* (Noble and Parker, 1926, de Villiers, 1934 a), the posterior portion of the prevomer overlies the palatine. According to W K Parker (1881) in *B. melanostictus*, there is a lopsided variation in the development of the palatine which, however, is not seen in my specimens.

(j) *The Nasal, Frontoparietal, Squamosal (paraquadrate Gaupp), Pterygoid, Quadratojugal (quadratomaxillary Gaupp) and Parasphenoid* —The variations noticed in these investing bones are minor and present no great morphological significance. The nasals may be so situated that the sphenethmoid is exposed between them and the frontoparietals, or as in *Nectophryne misera* and *Megophrys major*, the nasals may be separated anteriorly where the ossified tectum can be seen. The frontoparietals extend as far as the nasals anteriorly and posteriorly they cover the synotic region. I have not noticed any co-ossofication between the frontoparietals and the exoccipitals, but in *Philautus petersi*, the frontoparietals are united mesially and in *P. oxyrhynchus*, the frontoparietals of either side unite with the pro-otic bone. Both in *Megophrys major* and *Scaphiopus holbrookii*, the nasals and frontoparietals are studded dorsally with bony asperites, while in the other examples, the bones are smooth. With regard to the parasphenoid, the anterior end may show a divided appearance in some examples (*Scaphiopus holbrookii* and *Philautus petersi*).

The squamosal (paraquadrate Gaupp) in *Rana* is a triradiate bone according to Gaupp with an anterior, posterior upper and lower arms. In

the Microhylid examples studied by me, viz., *U. systoma*, *M. ornata* and *K. pulchra* (*K. p. taprobanica*), a gradual reduction in the development of the arms could be studied and the sequence of reduction being in the order, *Kaloula*, *Microhyla* and *Uperodon*. The posterior arm is reduced in *Kaloula* and *Microhyla* while it is absent from *Uperodon* (Devanesan, 1922). In *Glyphoglossus molossus*, it is not reduced. In the Ranid, Polypedatid, Bufonid and Pelobatid genera examined by me, the bone is typically Ranid in nature and these are, therefore, of no great significance.

In discussing the suspensorial region of *U. systoma*, *K. pulchra* (*K. p. taprobanica*) and *M. ornata*, I have said (author, 1932, p. 67) that "In *Kaloula* the processus quadratus becomes one with the processus pterygoideus and thus all the three, quadratomaxillary, paraquadrate and pterygoid invest this cartilage, while in *Rana* only the quadratomaxillary invests it." In all the Microhylid species examined and also in *Rana*, it is only the quadratojugal that invades the processus quadratus, while the squamosal and pterygoid invest it.

Now, in the descriptions of the cranium of the several Anura studied by me, I have designated the squamosal bone as the paraquadrate bone following Gaupp and de Villiers. According to the latter author (1936), 'the paraquadrate in the Anura is *not* an investing bone of the otic capsule and as such cannot be a squamosal'. Further, he points out that it is typically a membrane bone of the palatoquadrate, and adduces embryological evidence from the study of Urodela and describes a quadrato-maxillary in the apodan Boulengerula (1936). A year prior to the publication of this paper, Brock (1935) having studied the temporal bones in Lizards, Birds and Mammals, pointed out that, "There is no need for Gaupp's term 'paraquadrate' for the reptiles and amphibia, since it is merely a synonym for squamosal, a bone which may be defined as a membrane bone primarily associated with the lateral surface of the quadrate, with the migration of the quadrate (incus) into the tympanic cavity, the squamosal of the mammal secondarily becomes a bone of the otic capsule". Probably, de Villiers was not aware of this work (?) or at any rate, he does not refer to it. In the latest book on the development of the vertebrate skull, de Beer (1937) has pointed out that since Gaupp was not able to discover in Amphibia a squamosal of the type seen in Birds and Mammals, he called it a 'paraquadrate'. This view becomes untenable when we realise that 'the living Amphibia with their large quadrate cartilages are highly specialised, and that with the reduction of the quadrate to the incus which becomes protected by the tegmen tympani, the squamosal which covered the quadrate in the lower vertebrates, becomes a covering

bone of the auditory capsule in the higher forms . Thus, it becomes unnecessary to introduce the term paraquadrate for describing the squamosal

It may not be out of place here to remark that de Villiers (1936) has also discussed Gaupp's denomination of the quadratojugal as the quadratomaxillary. He points out that this is not a sesamoid bone and is represented by a quadrate squame in Gymnophiona where it is described as being absent. According to him, "Gaupp's nomenclature is followed in preference to what might be called a purely topographic one". Brock (1935) does not make a critical reference to this bone nor does de Beer (1937), though in describing the osteocranum of Amphibia, the latter author retains the term quadratojugal and treats it as a synonym of Gaupp's quadratomaxillary.

*Previous work* — I am only making a brief reference to these investing bones in the other forms that have been studied, the frontoparietals, nasals and the parasphenoid are not always normally disposed; in *Hemisus* (de Villiers, 1931 b), the sphenethmoid fuses with the nasals. In *Phrynomerus* (de Villiers, 1930 a), there is a large frontoparietal fontanelle, in *Cacosternum* (de Villiers, 1931, 1931a), these and the pterygoid and squamosal are Ranid in disposition, but the frontoparietals are poorly developed. In *Hemisus* (*op cit*) the pterygoid is normal while the anterior process is absent from the squamosal. The frontoparietals are fused together and is disposed over the nasethmoid. In *Breviceps* (de Villiers, 1932 a), the frontoparietals are separate while in *Probreviceps* the nasals and frontoparietals fuse together. In all the three genera (*Hemisus*, *Breviceps* and *Probreviceps*) the quadratojugal is absent, and probably on account of this, de Villiers notes that the squamosal and pterygoid have fused together. In *Ascaphus* (de Villiers, 1934), the nasals and frontoparietals are separate, similarly the pterygoid and squamosal. In *Rhombophryne* (de Villiers, 1934 a), the disposition of these bones is Ranid. In *Spelæophryne* (de Vos, 1935), the squamosal is reduced, the quadratojugal is absent and in the pterygoid and squamosal have fused and the frontoparietals are narrow bones. In the other examples (*Crinia*, *Rana grayi*, C du Toit, 1934 and 1933 respectively) and *Bufo* (Schoonees, 1930), the bones are normally disposed.

#### IV The Middle Ear Region

In sectional views the relationship of the pterygoid and squamosal to the middle ear and to the sound conducting apparatus is clearly made out. I shall now describe the sound conducting apparatus in brief. This consists of columella and stapes. According to Gaupp, the columella is

composed of three parts; a cartilaginous pars externa plectri (extra-stapedial of Parker) which abuts on the internal aspect of the tympanic membrane, a pars media plectri (mediostapedial of Parker) which is bony and an internal pars interna plectri (interstapedial of Parker) which plugs the anterior region of the fenestra where the cartilaginous operculum (stapes of Parker) closes or fits into the foramen ovale. In the Ranid forms (Gaupp) from the pars externa plectri arises a dorsal process (commonly met with in Reptilia) called the processus or pars ascendens plectri or laterohyal (suprastapedial of Parker) which gains attachment with the crista parotica. The tympanic membrane or tympanum, a modified region of the skin in that region is held taut by means of an annulus tympanicus cartilage. In some examples, the tympanum is 'hidden' being covered over by the unmodified skin. In the Microhylid examples studied by me, the tympanum is not externally visible or in other words the skin in this region is not modified to cover the tympanum. By 'hidden' we mean, therefore, the condition noted above. Günther, as early as 1858, described in detail the classification of Anurous Batrachians depending mainly on external and readily ascertainable characters, in which the question of "hidden tympanum" as described by Prashad (1918) and Boulenger (1920) is also discussed. Mivart (1869) in a paper "On the classification of Anurous Batrachia" utilises certain osteological characters some of which are drawn from Cope's studies. With regard to the ear, Mivart points out that he agrees with Günther, in that "the Batrachians with imperfectly developed ear would form together an unnatural group and would be separated too far from other allied forms". He divides, therefore, Anura, with reference to teeth, tongue and perfect or imperfect ear. Baini Prashad (1918) writing on the middle ear of Anura, introduced a new terminology, and on looking through his bibliography list, I find no reference to Günther (1858) and Mivart (1869). According to him, the 'tympanic area' is the name given "to the area of skin situated on the temporal patch on the side of the head. This area is continuous with the skin...". Further, the tympanic membrane "is quite a distinct structure lying immediately underneath the so-called tympanic membrane of authors. It can be easily separated from the skin covering it". It is obvious that it is unnecessary to use this fresh terminology, for Boulenger (1897, 1920) after referring to the previous workers, has remarked that, 'The tympanum, or drum of the ear, is absent in *Bombinator* and *Pelobates*. When present it may be concealed under the skin, as in some specimens of *Discoglossus*, *Pelodytes* and *Bufo vulgaris*, or appear on the temple behind the eye as a round or oval disc covered with thin skin'. Rightly does de Villiers (1930 a, p 689) point out in this connection that

" A ' hidden tympanum,' is in any case a dangerous cliché, for it is never anything but hidden, whether the superficial ectoderm is thin and transparent or thick and undifferentiated "

Now, with regard to the plectrum, it is noticed that in none of the Microhylid examples studied is a suprastapedial process developed. Further, the pars externa plectri expands into an oval cartilage on the inner aspect of the skin within the annulus tympanicus and on account of its expanded nature and its suspension from the end of the pars externa, it is not like the Ranid pars externa plectri, where the pars media attaches itself to the middle of the pars externa. This cartilage is therefore, composed of pars externa plectri plus the extraplectral cartilage. Whatever this difference may be, the pectral apparatus of the Anura can be homologised with the similar one noticed in Reptiles (Abel, 1929), if this view is not accepted by all, then there is no point in calling the cartilage extrastapedial, for the whole pectral apparatus is external to the operculum. Therefore, I have followed the terminology used by de Villiers and called it the " extra-pectral " cartilage. A brief reference may be made to the operculum. According to Versluys (1924) this structure is developed in response to the needs of a terrestrial life. In the terrestrial forms like *U. systoma*, *M. ornata*, *K. pulchra* (*K. p. taprobanica*) and *Glyphoglossus molossus*, the operculum is well developed and possesses a knob on the exterior aspect for the attachment of an opercular muscle. An operculum is also noticed by me in aquatic forms like *Rana hexadactyla*, *R. tigrina*, *R. cirtipes*, and Rhacophorid (Polypedatid) examples and in the terrestrial forms like the species of *Bufo* and in the arboreal *Nectophryne misera*. It would, therefore, be extremely interesting to make a comparative study of the development of this structure in these forms and examine if the statement which Parker (1934) makes with reference to the Microhylidae that 'the operculum is normal in the family and retains its muscular connection with the scapula' is applicable to the other families also.

*Previous work* —I have already referred to the classificatory importance of the ear region as discussed by Mivart (1869). The occurrence of a normal middle ear, eustachian passage and pectral apparatus is described in *Phrynomerus* (de Villiers, 1930 a), *Cacosternum* (de Villiers, 1931), *Anhydrophryne* (de Villiers, 1931 c), *Microbatrachella* (de Villiers, 1934 b), *Rana grayi* (C du Toit, 1933), *Crinia* (C du Toit, 1934) and *Spelaeophryne* (de Vos, 1935). In *Hemisus* (de Villiers, 1931 b) the middle ear, tympanic membrane, annulus tympanicus, eustachian passage and pectral apparatus are absent. Parker (1934)

also notices the same feature in *Melanobatrachus*, *Hoplophryne* (and presumably *Parhoplophryne* also). Similarly in Liopelmidæ (Wagner, 1934). While the plectrum and middle ear are developed in Aglossa (de Villiers, 1932), the eustachian tubes enter the buccal cavity by a median opening. The division of the tympanic cavity in *Probreviceps* is complete while in *Breviceps* (de Villiers, 1932 a) it is incipient. Further, in the former species an opercular portion of the *M. levator scapulae superior* is differentiated while the muscle and processus opercularis are absent from *Breviceps* and *Phrynomerus* (de Villiers, 1931 d). In this feature, these two examples differ considerably from the Microhylid character enumerated above and it may be noted here again that Parker (1934) has created a separate family for the accommodation of *Phrynomerus*. He also refers to the taxonomic importance of the ear region.

#### V (a) The Pterygoquadrate and its Attachments

In the larval condition of the Anura, it is noticed that the pterygoquadrate gains cartilaginous attachment with the cranium in three regions normally. The first is the quadratocranial commissure and in the majority of cases a quadrato ethmoidal commissure is also formed and is anterior to the quadratocranial one. The quadrato-ethmoidal commissure connects the processus maxillaris posterior of the lamina-orbito-nasalis and the processus pterygoideus of the quadrate. Next comes the processus ascendens which gains attachment with the pila antotica (or the orbital cartilage). Now, in some cases it is noticed that the pterygoquadrate may also give rise to a process in this region, which may articulate with the ventral wall of the cranium, if this palatobasal articulation is anterior to the palatine nerve (VII), it is described as the true basal articulation. In Anura generally, this process is posterior to the palatine branch of the seventh cranial nerve, and therefore, it is called the pseudobasal process and the articulation is similarly known as the pseudobasal articulation. In *Rana* (de Beer, 1937), a larval pseudobasal connection is formed and this is replaced by a pseudobasal articulation when the tadpole metamorphoses into the adult. Now, the last connection in anuran larvae is the processus oticus which unites the pterygoquadrate with the otic capsule over the carnoquadrate passage. This process lies laterally to the head vein and anterolaterally to the hyomandibular branch of facial nerve. Exceptions to what has been described above with regard to the pseudobasal process and the processus oticus are also found. When the tadpole undergoes metamorphosis, the larval quadratocranial commissure is lost and is

replaced by the quadratoethmoidal commissure, the processus ascendens disappears completely, the adult oticus connection is formed by the rotation of the processus muscularis and its subsequent fusion with the crista parotica. A pseudobasal articulation is found in *Rana* (incompletely autosylytic) while in *Bufo*, it is completely autosylytic. With this adult arrangement of the pterygoquadrate as the background, if we examine the Microhylid, Rhacophorid (Polypedatid), Ranid, Bufonid and Pelobatid genera studied, it is noticed that in all these, a pseudobasal process is developed. This articulates with the subocular shelf (there being no basitrabecular process) posteriorly to the palatine nerve and is ventral to the vena capitis lateralis. It is obvious from a review of the previous literature on this topic, that morphologists have followed Gaupp's nomenclature and called it the *processus basalis*, and it was de Beer (1926) who pointed out the difference between the true and pseudobasal processes. In all the forms examined by me [Microhylidae, 1932, 1932 a, Rhacophoridae, 1934 (Polypdeatidae), Ranidae (1935), Pelobatidae (1935 a) except Bufonidae (author, 1937)] there is an incomplete autosyly, however, in *Rhacophorus maculatus* (author, 1934, Plate, IX, Fig 5), there is a slight fusion of the internal end of the pseudobasal process with the ventral part of the otic capsule. Until the tadpoles of this species are examined, the significance of this connection is difficult to ascertain. At any rate, this is not like the one noticed in Bufonidae where the entire pseudobasal process fuses with the ventral wall of the otic capsule. An antorbital and an oticus connection are uniformly noticed in the forms examined by me.

*Previous work* —A pseudobasal process is described in all the species examined by de Villiers [except in *Ascaphus* (1934) where a true basal process is present] and by C and G du Toit, de Vos and Schoonees in the forms examined by them. The last author describes a complete autosyly in *Bufo angusticeps*. In *Hemisus* (de Villiers, 1931 b), the absence of a "basal" process is noted.

#### V (b) Arteria Carotis Interna

In describing the orbito-temporal and posterior region of the cranium, a brief reference may be made to the disposition of the arteria carotis interna. In the larval Anura (Gaupp, 1893, de Beer, 1937) it is noticed that the carotid artery becomes intramural after entering through the carotid foramen. Here it gives rise to the ophthalmica magna artery which gains exit through the metoptic foramen and the anterior and posterior cerebral arteries. The intracranial palatine artery which is also given off by the carotid gets out through the craniopalatine foramen. Now, when the tadpole undergoes

metamorphosis, the trabecular portion separating the metoptic foramen and the carotid artery breaks down, so much so that the vessels (ophthalmica magna and internal carotid arteries) look as though they enter the cranium through the oculomotor foramen. An anomalous condition, analogous to, though different from this is also noticed in some fishes like *Amiurus*, etc. In the Ranid forms examined by me, a similar disposition is also seen and I am examining the larvæ of these and also of the other genera to note if this phenomenon also occurs.

#### *VI Bursa angularis oris (Fuchs, 1931) or the Mundwinkeldruse*

The occurrence of this gland (?) was first described under the name of 'Mundwinkeldruse' by de Villiers in *Anhydrophryne* (1931c). It was later found to be present in some Amniote examples also and since the name Mundwinkeldruse was preoccupied, Fuchs (1931) introduced the phrase 'Bursa angularis oris' to describe it. This is a lymphocytic accumulation occurring in the angle of the mouth of frogs between the maxillary and pterygoid bones. In my study of this gland (1933 a), I have noticed that it uniformly occurs in all the four Microhylid examples, *U. systema*, *M. ornata*, *K. pulchra* (*K. p. taprobanica*) and *Glyphoglossus molossus*, further, it is also present in the Ranid and Rhacophorid (Polypedatid) genera examined. It is, however, wanting in Pelobatid and Bufonid examples studied by me. I have remarked that the exact function of the gland is not yet known and Muller (1932) has gone to the extent of questioning the glandular nature of it. The gland is ill-developed in *Glyphoglossus molossus* (young specimen) but well-formed in *Uperodon systema*, *M. ornata*, *K. pulchra* (*K. p. taprobanica*) and *Rhacophorus maculatus*. At the time I reported, I suggested that the probable line of evolution may have proceeded with *Glyphoglossus* as the starting point and the type seen in *Rhacophorus* as having taken its origin and proceeded on one side while that seen in *Kaloula*, *Microhyla* and *Uperodon*, on the other. This, according to me, is intended mainly to give an idea of the interrelationship of the Microhylid examples investigated by me. At the same time, I have cautioned that this is of no phyletic significance and particularly when we know that *Breviceps fuscus* lacks one and de Villiers (1933 a) himself is not quite sure if the other species of the genus *Breviceps* are devoid of it. This should not cause surprise for *B. fuscus* exhibits a series of peculiar features, as e.g., the reduced superior pres nasal cartilage, absence of palatine, sphenethmoid, quadrato-jugal bones and of an opercular muscle, the fusion of the cartilago obliqua posteriorly with the septum, the fusion of the pterygoid and squamosal bones and the absence of a "basal" process.

*Previous work*—The gland has been described in *Anhydrophryne* (de Villiers, 1931 c), *Probreviceps* (1932 a), *Rhombophryne* (de Villiers, 1934 a), *Spelæophryne* (de Vos, 1935), *Rana grayi* (C du Toit, 1933) and *Crinia* (C du Toit, 1934). In *Phrynomerus*, *Cacosternum* and *Hemisus*, de Villiers does not mention about the gland while in *Breviceps fuscus*, de Villiers (1931 d) notes the absence of the gland even though it is closely related to *Probreviceps* (de Villiers, 1932 a). Schoonees (1930) notes its absence in *B angusticeps*.

### VII The Lower Jaw

The lower jaw is characterised uniformly in the Anura by the possession of the two membrane bones, *viz.*, the angular and the dentary and a single cartilage bone—the mentomandibular. The membrane bones are investments of Meckel's cartilage. The dentary is only met with in the anterior sections of the lower jaw. In the Microhylid examples studied, *viz.*, *U systema*, *M ornata*, *K pulchra* (*K p taprobanica*) and *G molossus*, there is a Meckelian epiphysis which projects postero-internally (author, 1932 b) parallel to the jaw on either side. The presence of this was first noticed by Devanesan (1922) in *U systema*. In the foreign Phrynomeridae and Microhylidae studied by de Villiers, its occurrence is also noticed (*Phrynomerus* 1930 a, *Breviceps* 1931 d, *Probreviceps* 1932 a, *Rhombophryne* 1934 a, and by de Vos in *Spelæophryne*, 1935). In *Cacosternum* and *Hemisus* (de Villiers, 1931 and 1931 b respectively) it is absent and therefore, they do not show this Microhylid affinity. It may be pointed out here that in the Ranid, Rhacophorid (Polypedatid) and Bufonid examples studied by me, the epiphysis is absent. Further, de Villiers (1934 b) discovered the absence of it in *Microbatrachella*, and therefore, excluded it from the Microhylidae; he notes (p 414) "I agree with Ramaswami (1932 b) that 'it is a lateral epiphysis of Meckel's cartilage uniformly occurring in the Engystomatidae'". The absence of this process in *Microbatrachella* definitely excludes the genus from Brevicipitidae. . ." From the same point of view, *Cacosternum* and *Hemisus* cannot be included under Microhylidae and rightly does Parker (1934) omit these two from the Microhylid family. Thus, this character of the possession of Meckelian epiphysis will be very useful in discussing the affinities of the Microhylid genera.

### VIII The Hyolaryngeal Apparatus of Microhylidae and Pelobatidae

As already pointed out, I have studied the sectional views of the larynges of both sexes of *U systema*, *M. ornata* and *K pulchra* (*K. p taprobanica*) and the gross anatomy of the larynges of various Ranid and Rhacophorid (Polypedatid) species. With regard to the Microhylid hyolaryngeal

apparatus, I have recorded certain interesting features, everyone of which has been confirmed by the later worker Trewavas (1933) and in a personal communication, she has stated that my paper (author, 1932 b) was unfortunately not available to her at the time. I have also studied the gross anatomy (1935 b) of the hyolaryngeal apparatus of Pelobatidæ, and noted that there is considerable variation with regard to the cricoid element. With regard to the hyoid apparatus, I have shown that a demarcation line could be drawn between the subfamilies Megophrynæ and Pelobatinæ. In the case of the Megophryne hyoid apparatus, a lateral foramen is absent while in the Pelobatinæ, it is well developed. There is, however, one exception. In the case of *Megophrys feae* (Beddard, 1911) the occurrence of a lateral foramen is noted, and this escaped my attention when I wrote my paper. Further, in the case of *Pelobates fuscus*, W K Parker (1881) does not depict a lateral foramen, though according to the observation made above, the hyoid of Pelobatinæ must possess a lateral foramen. Probably, Parker's delineation is incorrect, or it is an individual variation, for it is noticed that in his paper on the development of the hyoid apparatus of *Pelodytes*, Ridewood (1897, Fig 12) draws, for comparison, a figure of the hyoid of *Pelobates fuscus*, where a lateral foramen is clearly shown. Thus, so far as is known to me, the Pelobatine hyoid apparatus possesses a lateral foramen while in the case of *Megophrys* (except *M. feae*) the lateral foramen is absent and *M. feae* may be treated as a connecting link between the two.

Now, with regard to the hyolaryngeal apparatus of the Microhylid examples studied (author, 1932 b), the following important points are noted:

- (1) The hyoid plate has a cartilaginous or bony, beak-like portion between the postero-medial processes. This feature was already noticed by W K Parker (1881) in *Callula pulchra* and two species of *Microhyla* which he described under the name of *Diplopelma*, *D. ornatum vel rubrum*, and *D. Berdmorei* (?) It is rather unfortunate that neither Trewavas (1933) nor myself referred to *Kaloula* and *Microhyla*, though Trewavas did refer to *Gastrophryne* of Parker (1881). With regard to *Microhyla*, the difference in nomenclature is responsible.
- (2) An extra-hyal associated with the anterior cornu is well represented. Parker (1881) does not draw the occurrence of an extra-hyal in his specimen of *Callula pulchra*. Trewavas (1933) notes its presence in *Microhyla okinavensis*, an extra-hyal is absent according to Frazier (1924).

- (3) A cartilage of Santorini (cartilago apicalis Gaupp) is absent
- (4) The cricoid annulus does not possess an oesophageal process (spina oesophagea Gaupp) This process is commonly met with in the female specimens of the Ranid species studied by me However, in only two examples of Ranids, viz., *Rana tigrina* and *R. breviceps*, the male may also possess this process though this feature is not uniformly noticed Therefore, this is an erratic variation and no importance need be attached to it Thus, since the oesophageal process was noticed in all the Ranid females examined by me, it may well be used as a sex determiner
- (5) The bronchial processes are long and embrace the root of the lung as expanded plates

And to these characters Trewavas (1933) adds five more, four of which are with regard to the musculature of the hyolaryngeal apparatus and the other with reference to the postero-medial processes of the hyoid apparatus. These characters taken together exclusively distinguish the Microhylid hyolaryngeal apparatus from that of the others

I have mentioned on p 40 of my paper (1932 b) that *Microhyla* and *Kaloula* are devoid of a vocal sac, an observation made on insufficient material I have since examined the male members and have discovered the presence of a small vocal sac, and as early as 1882, Boulenger reported the occurrence of a vocal sac in the South Indian Microhylid genera Parker (1934), who has described these forms, also notices the presence of vocal sac in *Kaloula* and *Microhyla* In *Uperodon systoma*, Devanesan (1922) also draws attention to the occurrence of a large vocal sac

*Previous work* —Trewavas (1933) gives us an exhaustive account of previous workers on this subject However, she does not refer to some of Blume's papers, and they are W. Blume (1931, 1932 and 1933)

#### IX The Vertebral Column

The examination of the vertebral centrum in the Ranid and Rhacophorid (Polypedatid) families has revealed some important variations At the time of writing my paper (1933), I was not able to secure Nicholls' paper (1915-16) which deals with the classificatory importance of the vertebral column in Anura I have noted that in the case of *Rhacophorus (Polypedates) dubius* and *R. microtympanum*, the 8th vertebra is procoelous, while in *R. maculatus* and *R. eques* it is diplasiocoelous,—a term invented to represent the double concave nature of the centrum by Boulenger I have

confirmed Nicholls' observation (1915–16) of the diplasiocœlous nature of the centrum in *Rhacophorus maculatus*. Mookerjee's observation (1932) on *Rhacophorus maximus* was already anticipated by Nicholls. And with regard to the genus *Rhacophorus* (*Polyptedates*), I have stated (author, 1933) that so far as the characters of the 8th and 9th vertebrae are concerned, it could be split into two. Under the procœlous Rhacophoridae (*Polyptedatidae*), we have to treat probably the procœlous species of *Philautus* examined (*Philautus chalazodes*, *P. nasutus* and *P. oxyrhynchus*) and if more species are discovered with pro- or diplasiocœlous type of centrum of the 8th vertebra, then, this would be another feature, besides the prevomerine teeth and sphenethmoid, to support Noble's view that *Philautus* is not a single distinct genus but a polyphyletic assemblage. In passing, it may be noted, that from the view-point of cranial anatomy, there is a vast body of evidence disproving Noble's dictum that *Philautus* does not represent a natural genus. In the family Ranidae, a large number of species exhibits the diplasiocœlous 8th vertebra. With regard to the genus *Micrixalus*, I have stated (author, 1933) that in the possession of diplasiocœlous (incorrectly stated as procœlous, p. 1, column 2, line 27) 8th vertebra, "*Micrixalus* is Ranid in every respect". The three species of *Nyctibatrachus*, the majority of the species of *Rana* (except *Rana curtipes* Jerd., and *R. tenuilingua* Rao) examined by me are diplasiocœlous. In *R. curtipes*, however, the 8th and 9th vertebrae are fused and there is a single centrum and the zygapophyses are a pair in number (anterior). The transverse processes are Ranid in character, but in one specimen of *R. curtipes*, the right transverse process of the 9th vertebra is absent and the ilium gains attachment with the transverse process of the 8th vertebra. The fusion of the 8th and 9th vertebrae is noticed in all the specimens of *R. curtipes* examined by me, so much so that it is a distinguishing character of this species and the position of this with reference to the other genera where fusion of the vertebral elements occurs, is discussed in my paper (author, 1933).

When Nicholls discovered the diversity in the vertebral column of the genera *Rana* and *Rhacophorus* of the family Ranidae [the Rhacophoridae (*Polyptedatidae*) being included under it], he noticed the difficulty of including the genus *Rhacophorus* under the family Ranidae. He says, "The genus is one in which Boulenger has merged the genus *Polyptedates*, and it is represented in the British Museum collection of skeletons by nine specimens. Of these, four belonging to the species *R. maculatus*, *R. cruciger*, *R. macrotis* and *R. robustus* were diplasiocœlous. The remaining specimens *R. maximus*, *R. madagascariensis*, *R. schlegelii* and *R. reinwardtii* were uniformly procœlous". Noble (1931, p. 514) has treated the suborder diplasiocœla

(the true frogs, Ranids, old world tree frogs, polypedatids and narrow-mouthed toads, brevicipitids) as comprising three families, viz., Ranidae, Rhacophoridae (Polypedatidae) and Brevicipitidae. The Rhacophoridae (Polypedatidae) are differentiated from the Ranids by the presence of an intercalary cartilage between the distal and penultimate phalanges. Under the subfamily Raninae come the species of *Rana*, *Nyctibatrachus* and *Nanobatrachus* and under the subfamily Cornuferinae, is treated *Micrixalus*. With regard to the two genera *Philautus* (*Ixalus*) and *Micrixalus*, Noble (1931) states that " *Philautus* has arisen from *Polypedates* in many parts of its range by the oft repeated process, a loss of vomerine teeth" and treats this under the family Rhacophoridae (Polypedatidae). I have shown elsewhere (author, 1934) that cranial anatomy does not support the merging of *Philautus* with *Rhacophorus* except when the dentition of the prevomers, the sphenethmoid and the nature of the vertebral centra of 8th and 9th are taken into consideration (see p. 69). *Micrixalus* is described by Noble (1931) as a group of small species of *Hylarana* lacking vomerine teeth. Thus both these genera *Micrixalus* and *Philautus* while possessing digital expansions lack vomerine teeth, but *Philautus* is a Rhacophorid (Polypedatid) with intercalary phalanges, and *Micrixalus* a Ranid without them. Therefore, the view "that the separation of *Micrixalus* from *Ixalus* is based on arbitrary grounds and possibly when a large number of species is examined the diagnostic characters of the two genera may be found to be too slender for erecting two genera for their reception" (author, 1933) is not tenable.

#### *IX The Vertebral Column of Megophrys major (author, 1935 a)*

In the preparation that I have of the vertebral column of *M. major*, the 1st and 2nd vertebrae are fused, and therefore, I have stated that it differs from the ancestral form, the Liopelmidæ. The ancestral forms possess ten vertebrae and the first forms of Pelobatidæ to be derived from these are the Megalophrynae (Megalophrynae) and one of the species of this group *M. major* examined by me, therefore, differs from the ancestral stock in the possession of only 8 vertebrae. I have now examined another specimen of the same species and have discovered that the 1st and 2nd vertebrae are not fused, and therefore, the normal form differs from the ancestral stock in possessing 9 vertebrae. The one with fused 1st and 2nd vertebrae shows therefore, a variation. Further, in my 1st specimen, the coccyx is partially united with the sacrum though Boulenger finds it immovably united in his specimen of *M. major*. Parker, after an examination of a large number of species of Megalophryns including *M. major*,

informs me (in litt.) that in normal cases of *M. major*, a small subcircular cartilaginous omosternum is present. He also points out that in his specimen of *M. major*, the coccyx is incompletely fused with the sacrum as in mine and unlike that of Boulenger's. Probably Boulenger failed to see the non-fusion.

In discussing the ancestry of Pelobatidae, I have followed the observations of Noble (1924, 1931). According to him, the Liopelmidæ are the most primitive Anurans. This group has given rise on the one hand to the Discoglossidae and on the other to the Pelobatidae, and cranial morphology supports this origin of the Pelobatidae from the Liopelmid stock in 4 features. They are the absence of a recessus sacciformis, of a Bursa angularis oris and the presence of a septomaxillary and the fusion of the mentomandibular with the dentary. It is true that any one of these features may be found in any other Anuran family but when we take all these four features together, Noble's hypothesis is amply borne out by cranial anatomical studies.

#### X Summary and Conclusions

It has been known from a long time that Anuran families cannot be distinguished systematically from one another by a single character but by a set of features. With this in mind, we shall now proceed to examine the various features that the cranial morphological investigations have revealed.

1. The cartilago prenasalis superior and inferior are uniformly met with in the Anura. Exceptions, however, are very few where either the superior is reduced (*Breviceps fuscus*) or the inferior cartilage is absent (*Hemisus*). Thus, this character is of no diagnostic importance.

2. The cartilago obliqua is a lateral extension in the anterior narial region from the tectum and from this a connective tissue projection—the plica obliqua depends into the cavum. Gaupp who studied *Rana fusca* (*S temporaria*) noticed that it depended from the cartilaginous roof and not from the cartilago obliqua and the same feature as reported for *Rana fusca* is also seen in *Breviceps fuscus*. Now, in the Rhacophorid (Polypedatid) forms examined by me, it is noticed that in three species of *Philautus*, the plica depends from the tectum, while in the species of *Rhacophorus* (*Polypedates*), it depends from the cartilago obliqua. In the Ranids, Bufonids and Pelobatids examined by me and in the forms studied by the South African anatomists (with the exception mentioned on pp 46 and 47), the plica depends from the cartilago obliqua. While the nature of the dependence of the plica cannot be made use of for classificatory purposes in other families, at any rate in the Rhacophoridae (Polypedatidæ), it

appears to be useful in the present state of our knowledge, in distinguishing *Philautus* from *Rhacophorus* (*Polypedates*)

3 The prechoanal sac which may occur as two sacs in the anterior region into which the choanæ open or as a single sac (*Rhacophorus maculatus* and *Megophrys major*) or as a vestigial structure (*Uperodon systoma*) into which the choanæ do not open, is also noticed in other forms like *Phrynomerus* (double), *Probreviceps*, *Breviceps*, *Spelæophryne*, *Rhombo-phryne* and *Rana grayi*. It is absent from *Glyphoglossus molossus*, examined species of *Rhacophorus* (except *R. maculatus*) and *Philautus*, *Bufo*, and from *Scaphiopus holbrookii* and *Nectophryne misera*. Since the occurrence of this is noticed in genera, of different families, it is probably of independent origin and does not show, therefore, any relationship. Obviously, this cannot be used in systematic study.

4 The septum nasi which is either cartilaginous or is posteriorly ossified gives rise to the tectum or the roof and the solum or the floor. The solum is noticed to give rise to an elevated eminentia in a large number of forms comprising Microhylidæ, Ranidæ, Bufonidæ and Pelobatidæ. It was theorised by the South African anatomists that the occurrence of an elevated eminentia was closely correlated with a terrestrial mode of life. This is true in the case of forms like *Uperodon systoma*, *Microhyla ornata*, *Kaloula pulchra* (*K. p. taprobanica*), *Glyphoglossus molossus*, *Breviceps*, *Probreviceps*, *Spelæophryne* and other forms like *Bufo* and *Hemisus*. The appearance of this structure in different forms can only be explained as due to independent development. If only the terrestrial forms developed this structure, of course the theory advanced would not have been found fault with. In two typically aquatic forms of South India, *Rana hexadactyla* and *Rana cyanophlyctis*, an elevated eminentia is met with, and it is therefore thought, that the elevation is purely in response to the sensory needs of the animal. Whatever this aspect of the question may be, it is interesting to note that the Microhylid genera so far studied, viz., *Microhyla*, *Uperodon*, *Kaloula*, *Ramanella*, *Breviceps*, *Probreviceps*, *Spelæophryne* and *Rhombo-phryne* (?), the elevated eminentia uniformly occurs and this character therefore, can be utilised along with other features in distinguishing the Microhylids.

5 The sphenethmoid bone. It has been noticed that in some examples this bone is divided by means of a trabecular cartilage into a right and left portions when the bone is described as paired. A complete sphenethmoid is seen in *Rhacophorus maculatus*, *Philautus petersi*, *P. oxyrhynchus*, *Rana cyanophlyctis*, *R. hexadactyla*, *Megophrys major* and *Scaphiopus holbrookii*.

while in *U. systoma*, *K. pulchra* (*K. p. taurobanica*), *M. ornata*, *G. molossus*, *Rhacophorus microtympanum*, *Philautus chalazodes*, *Phrynomerus* and *Rhombophryne* it is paired, in some, it may be absent like *Spelæophryne*, *Ascaphus* and *Rana curtipes*, etc. We find that in the case of all Microhylid examples so far studied, it is either paired or is absent (*Spelæophryne*, *Breviceps*, *Probreviceps*, *Kalophrynx*, *Callulina*, etc.) In the Ranidæ, it may be absent or it may be single or paired [though Päker (1934) says that the ethmoid is single] and we meet with the same state of affairs in Rhacophoridae (Polypedatidæ). Hence, this character of the paired nature of the sphenethmoid can be conveniently utilised with others in describing the family characters of the Microhylidæ, till we find other exceptions. With regard to the Ranidæ and Rhacophoridae (Polypedatidæ), the sphenethmoid can be described as either single or paired or absent (some Ranidæ). More examples should be studied before we can come to any conclusion with regard to the sphenethmoid of the Bufonid and Pelobatid families.

6 The maxillæ and premaxillæ are not of great importance to us in systematic study of the genera examined by me.

7 The prevomer, in the Ranid and Rhacophorid (Polypedatid) families does not embrace the choana posteriorly and is not flat. This observation is supported by *Rhacophorus maculatus*, *R. microtympanum*, *Philautus chalazodes*, *P. oxyrhynchus*, *P. petersi* and *Rana hexadactyla*, *R. curtipes* and *R. cyanophlyctis*. In the Microhylid forms studied by me, *U. systoma* exhibits a well-developed prevomer and a degenerate palatine (?), in *M. ornata*, the choana is not embraced posteriorly by the prevomer, while in *K. pulchra* (*K. p. taurobanica*), the posterior portion of the prevomer overlies the palatine. In *G. molossus*, there is a postchoanal portion (prevomer or prevomeropalatine). Thus, in the Microhylid family, we meet with conditions where the choana may be completely or incompletely (*Kaloula*, *Glyptoglossus*, *Rhombophryne*, *Spelæophryne*, *Breviceps*, *Probreviceps*) or may not be surrounded by the prevomer as in *Microhyla*. Therefore, the nature of the prevomer is not only useful in distinguishing the family but also in classifying the genera within it. Whether the statement can be applied to the Bufonidæ and Pelobatidæ can only be settled after examining some more genera.

8 The palatine bone is not so useful as the prevomer. This may be degenerate (*U. systoma* ? for the bone may also be described as a postchoanal prevomer), or absent (*M. ornata*) or a pre-vomeropalatine arrangement may be seen. Generally in the Ranidæ, Rhacophoridae (Polypedatidæ), Bufonidæ and Pelobatidæ, the bone is present, however exceptions are not

uncommon *Nectophryne misera* and *Scaphiopus holbrookii* can be mentioned as instances Among the several species of *Microhyla*, some possess it, while others do not Thus, the nature or the disposition of this bone cannot be utilised in taxonomy

9 The septomaxilla is noticed to occur uniformly in all the forms examined by me This is not, therefore, of great systematic importance except in one case In *Bufonidae*, a limb of the septomaxilla appears in the plica, a feature in which this family stands apart from the others I am aware of an exception to this, in *Bombinator*, Brüner describes a limb of the septomaxilla in the phica Barring this exception, it will be found useful to introduce this feature of the septomaxilla in describing the family characters of the *Bufonidae*

10 The middle ear and associated structures. It is very well known that in widely different forms, the disappearance of the middle ear, eustachian passage, tympanum and plectral apparatus may occur, as in *Liopelma*, *Ascaphus*, *Hemisus*, *Pelobates*, etc This may not establish any genetic affinity and therefore, the disappearance of these structures fully or otherwise should be considered secondary Overlooking these genera, there is a common plan on which the middle ear region with its associated structures is built The attachment of the columella (pars media plectri) to the dorsal rim of the extraplectral (pars externa plectri plus extraplectral) cartilage in the Microhylid examples examined by me, associated with a sickle-shaped annulus tympanicus, is certainly different from the median attachment of the columella with the pars externa noticed in *Ranidae*, *Rhacophoridae* (*Polypedatidae*) and *Pelobatidae* Since this feature is not uniformly noticed in the other species of the Microhylid family, it cannot be used as a safe criterion The pars ascendens plectri deserves to be mentioned. Gaupp described this commissural cartilage (laterohyal) in *Rana*, but this has not been confirmed by me in all the species of *Rana* examined or in the Rhacophorid (*Polypedatid*) species studied In Bufonid species (except *Bufo vulgaris*), a laterohyal is noticed, and this internal character can therefore be utilised in describing the family characters It may be said that Bufonids generally posses a laterohyal

11 The pseudobasal joint. In the Anura, the pseudobasal joint between the subocular shelf and the pseudobasal process (except in *Ascaphus*) of the pterygoquadrate is common. In the Ranid, Rhacophorid (*Polypedatid*) and Pelobatid families, the pseudobasal articulation is found while in Bufonid species studied, there is a definite pseudobasal connection This is a distinguishing feature of the *Bufonidae*. Whether it is

an articulation or a connection it always lies posterior to the palatine branch of the facial nerve and is ventral to the head vein. In describing the family characters of Bufonidae, the possession of a complete autosystyle should also be included.

12. The Bursa angularis oris or Mundwinkeldruse is noticed in Microhylidae (except *Breviceps fuscus*), Ranidae and Rhacophoridae (Polypedatidae) and is generally absent from Bufonidae and Pelobatidae. In describing, therefore, the family characters of the first three, the presence of the Bursa may also be included.

13. The occurrence of a bony or cartilaginous beak between the posteromedial processes of the hyoid (called basi-brachial by Parker, 1881) is uniformly noticed in the South Indian Microhylid examples, but in the foreign forms *Breviceps*, *Probreviceps*, *Spelaeophryne* and *Rhombophryne*, this is not present; all the same, Trewavas considers this as a distinguishing character of the *Gastrophryne* group of the Brevicipitidae. This feature is of no great systematic value in general but is of sufficient importance to demarcate the examined Indian genera. To this may be added, the absence of an omohyoid and the presence of only two petrohyoideus muscles (Trewavas) and these three characters are very useful in distinguishing the Microhylidae. The larynx of the Microhylidae exhibits two important diagnostic features, viz., the absence of an independent apical cartilage and of an oesophageal process from the cricoid annulus of both sexes. With regard to the Pelobatidae, the presence of a lateral foramen in the Pelobatinæ would distinguish the Megophrynæ (except *M. feae*, where also a lateral foramen is present). Following Trewavas, the diagnostic features of the Pelobatid family would be as follows—

- (a) The occurrence of an arytenoid without an apical cartilage,
- (b) cricoid ring incomplete dorsally [except in *Scaphiopus hammondii* (male) where it is complete] (author, 1935 a), and
- (c) hyalia more or less reduced

14. The occurrence of a Meckelian epiphysis is so characteristic of Microhylidae that it ought to be included as a taxonomic feature. However, we note the occurrence of a Meckelian epiphysis in *Phrynomerus*, which has been treated as belonging to the subfamily Phrynomerinae under Brevicipitidae by Noble (1931). Besides, *Phrynomerus* also shows other Microhylid affinities, as dilated sacral diaphysis, prechoanal prevomer (Parker, 1934) as in *Microhyla* (but de Villiers (1930 a) describes the formation of a prevomeropalatine in (*Phrynomerus*), divided ethmoid, etc. In spite of all these features common with the Microhylidae, Noble says that, "The

African *Phrynomerus* is not closely related to any other brevicipitid." Whatever may be the number of similarities between this genus and the other genera of Brevicipitidae of Noble, there is one important distinguishing feature and that is, the presence of intercalary phalanges. No Microhylid possesses these, and therefore, Parker (1934) has erected a new family Phrynomeridae for accommodating this genus.

15 The nature of the centrum of the vertebrae has been utilised largely in taxonomy. Within the family Ranidae and Rhacophoridae (Polypedatidae), I have shown that both the procœlous and diplasiocœlous type of centrum for the 8th vertebra occur. Therefore, in distinguishing families this may not be a safe criterion, and it must be said that the propriety of using the nature of the vertebra has been questioned from the time of Gadow since the variations noticed have been largely fortuitous. At any rate, I have no hesitation in following Parker (1934) for using the nature of the centrum in the diagnosis of groups of genera within the families.

#### *Conclusions*

The study of cranial morphology and of the hyolaryngeal apparatus and the vertebral column reveals the following features which can safely be utilised along with others (Parker, 1934) in the classification of Anuran families and subfamilies.

#### *Ranidae*

- (a) Vertebral column diplasiocœlous or procœlous
- (b) Ethmoid entire or paired or absent
- (c) Eminentia generally flat except in *Rana hexadactyla* and *Rana cyanophlyctis*
- (d) A Bursa angularis oris is present
- (e) A pseudobasal articulation is noticed

#### *Rhacophoridae (Polypedatidae)*

- (a) Vertebral column diplasiocœlous or procœlous
- (b) A Bursa angularis oris is present
- (c) A pseudobasal articulation is noticed

#### *Microhylidae*

- (a) Eminentia is invariably elevated
- (b) A Bursa angularis oris is present
- (c) A Meckelian epiphysis is present on either side in the lower jaw
- (d) An independent cartilago apicalis is absent from the arytenoid cartilage.
- (e) An œsophageal process is absent from the cricoid annulus

*Bufoidea*

- (a) Invariably a limb of the septomaxilla is seen in the plica obliqua
- (b) A Bursa angularis oris is absent
- (c) A pseudobasal connection is present
- (d) A laterohyal is invariably present

*Pelobatidae*

- (a) A Bursa angularis oris is absent
- (b) A pseudobasal articulation is present
- (c) The cricoid annulus is complete or incomplete
- (d) The hyoid of the subfamily Pelobatinae possesses a lateral foramen while in Megophrynae, it is wanting except in *M. feae*

*XI Acknowledgement*

I must acknowledge my indebtedness to Professor C R Narayan Rao, under whose guidance, the work embodied in the several papers, which forms the basis of the present review was carried out from time to time. I must also express my sense of gratitude to Professor E S Goodrich, M.A., F.R.S., of Oxford, to Dr G R de Beer, D.Sc., of London and to Mr H W Parker of the British Museum, for their constant guidance and help with literature. My thanks are also due to Professor A Subba Rau, D.Sc., for helpful criticisms.

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## ERRATA LIST

*Half-yearly J. Mys Univ., 1932, 6, Nr 1*

Reprint page	Journal page	Line	
3	34	1	<i>read "Microhyla okinavensis and Cacopus"</i> <i>for "Microhyla and Caropus"</i>
3	47	last but one	<i>read "like in all" for "like all".</i>
11	55	23	<i>read "Miss Lapage (13)" for "Lapage (11)"</i>
23	67	15	<i>read "crista parotica, which is to be seen" for</i> <i>"crista parotica is to be seen"</i>
23	67	35	<i>read "Anura (Gaupp) is not accepted" for "Anura</i> <i>(Gaupp)</i>

*Half-yearly J. Mys Univ. 1932, 6, Nr 2*

1	176	21, 24	}
4	179	22	
5	180	10	
6	181	28	
7	182	12	

*Proc Ind Acad Sci, 1935, 2*

2	12	<i>read "cartilago alaris" for "cartilago obliqua"</i>
20	28	<i>read "172" for "162"</i>

*Proc Ind Acad Sci, 1934, 1*

87	8	<i>read "(See fig 9)" for "(See fig 8)"</i>
93	34	<i>read "1932" for "1933"</i>
94	25	<i>read "CLXXII" for "CLXII"</i>

Page X fig 5. lettering .. . *read "U B." for "V B."**Proc Zool. Soc Lond, 1937, Part 4*

1165	7	<i>read "B. melanostictus and B. parietalis" for</i> <i>"B melanostictus and B pantherinus".</i>
1168	52	<i>read "CLXXII" for "CLXII"</i>

*Current Science, 1933, 1, Nr 10.*

Page 1	Column 1 Line 32	<i>read "R intermedius (n sp Rao)" for "R. intermedius".</i>
	2	<i>read "amphicelous (diplosiocelous)" for</i> <i>"prococelous"</i>
2	1	<i>read "a pair" for "two pairs".</i>

# OXIDATION OF THIOLS AND ASCORBIC ACID IN THE LATEX OF PAPAYA

BY C V GANAPATHY AND B N SASTRI

(From the Department of Biochemistry, Indian Institute of Science, Bangalore)

Received July 10, 1959

It was pointed out in an earlier paper<sup>1</sup> that the fresh latex of papaya (*Carica papaya*, Linn) contains a remarkably large concentration of sulphhydryl compounds (amounting to nearly 2 per cent calculated as glutathione) and that practically the whole of it is in the reduced form. The actual glutathione content of the latex is about 0.2 per cent. It has now been found that vitamin C co-exists with glutathione and that the whole of it is also in the reduced condition.

Considerable attention has been devoted to the elucidation of the mechanism, present in the tissues, responsible for maintaining glutathione in the SH-form. Hopkins and Elliot<sup>2</sup> showed that liver tissue contains thermolabile catalysts responsible for the reduction of glutathione. Glucose dehydrogenase,<sup>3</sup> a system present in the intact mammalian erythrocytes<sup>4</sup> and the Warburg-Christian enzyme<sup>5</sup> are all known to be capable of reducing GSSG to GSH. It is of interest to enquire whether the papaya fruit also contains thermolabile catalysts, which function in an analogous manner and incidentally ascertain the nature of protection afforded to vitamin C against oxidation. A preliminary communication on the subject appeared in *Current Science*.<sup>6</sup>

## Experimental

### I THE SYSTEM GSSG $\rightleftharpoons$ GSH

(1) *The influence of aeration on the SH concentration of the papaya latex* — 5 gm samples of the fresh latex, drawn from plants grown in the Institute nursery, were weighed into a series of wash bottles (300 c.c. capacity) dispersed in 40 c.c. phosphate buffer (pH 7.4) and aerated by sucking in air with the help of a filter-pump. At intervals of 2 hours the contents of the bottles were transferred to a glass mortar, rubbed with trichloracetic acid (20 per cent) and sand, and filtered on a Buchner. The residue was repeatedly extracted with trichloracetic acid until the filtrate gave a negative test with nitro-prusside. The combined filtrate was made up to 100 c.c., sufficient water being added to bring the final concentration of the trichloracetic acid to 10 per cent. 5 c.c. aliquots were used for the estimation of SH. Two methods were employed for the purpose —(1) Iodometric titration according to the method of Kuhnau<sup>7</sup> and (2) the colorimetric

method employing the photoelectric colorimeter. This method developed in our laboratory has been described elsewhere.\*

The results obtained with different samples of latex are given in Table I\*. The figures represent c.c. of N/100 iodine required for titrating the SH groups present in one gram of the latex. Temperature 25°C.

TABLE I

Aeration Time (Hrs.)		0	2	4	6	8	10	12
Sample 1	..	8.2	8.4	8.0	4.4			2.4
"	2 ..	10.0	10.1	8.8	7.6	6.8	.	.
"	3 ..	7.5	7.5	6.7	5.1			
"	4 ..	7.8	7.7	6.6	5.4	4.5	3.24	2.4
"	5 ..	6.8	6.7	5.1	3.2	..	.	.
"	6 ..	7.3	7.4	5.7	4.2	.	2.1	,
"	7 ..	6.7	6.6	4.9	3.3		..	.
"	8 ..	8.4	8.4	6.6	4.8	.		1.9
"	9 ..	7.1	7.1	6.3	5.1		2.5	..
"	10 ..	8.8	8.8	7.2	6.0	5.2		2.4
"	10† ..	7.5	7.4	5.9	4.8	3.8	.	.

(2) *The influence of preliminary heating of the latex on the oxidation of SH groups during aeration*—In the second series of experiments the latex was dispersed in phosphate buffer (pH 7.4) as before, raised to a temperature of 50°C., at which temperature, it was maintained for 60 minutes, cooled

\* The titre values tabulated in this section have to be corrected for the presence of ascorbic acid. The main conclusions obtained from these experiments, however, will not be affected, as the titre value for ascorbic acid remains constant until almost all the thiols are oxidised, as will be shown in the subsequent part of the paper. The values for the SH concentration determined by the photoelectric colorimeter are not subject to this error.

† The figures refer to the values calculated in terms of  $\frac{N}{100}$  iodine obtained with the photoelectric colorimeter, only results for sample 10 are given here. The difference between the values by the two methods is due to the ascorbic acid.

and aerated. Subsequent treatment was the same as before. The results obtained are shown in Table II.

TABLE II

Aeration Time (Hrs.)	0	2	4	6	8
Sample 1	7.5	5.3	4.2	2.3	1.2
,, 2 .	6.7	4.3	3.0	1.9	0.8
,, 3	7.0	5.1	4.0	2.4	.
,, 4	5.8	3.7	2.5	1.3	0.2

The results in the first series of experiments show that there is no fall in the SH concentration during the first two hours of aeration, after which there is almost a linear fall. In a few instances, there is a tendency towards a slight increase in the SH concentration. When the latex is heated to 50° prior to aeration, however, there is a steady fall in the SH content from the very commencement of aeration. The SH content remains at a constant level during aeration only if a reducing mechanism capable of reconverting the SS to the SH form is present in the latex. If such a mechanism is present, addition of fresh SS compounds should lead to an increase in the SH concentration of the reaction mixture on incubation.

(3) *Influence of the added SS compounds on the SH concentration of the latex*—The effect of addition of SS compounds prepared from the latex itself, was examined in the third series of experiments. The thiols were extracted by boiling the fresh latex with water and oxidised with iodine or hydrogen peroxide. In the case of iodine the quantity required for oxidation was determined by direct titration, with  $H_2O_2$ , the aqueous extract of the latex was raised to pH 9 by adding NaOH, then  $H_2O_2$  was added and after oxidation was completed (as shown by negative test with nitro-prusside) the excess of  $H_2O_2$  was removed by boiling. The resulting solution was finally brought down to pH 7 by hydrochloric acid and used. A solution of the SS compounds (1 per cent concentration) was mixed with fresh latex and after 4 hours incubation, the SH content was again determined by iodometric titration. The results given in Table III clearly show that there is an increase in the SH content over the initial value, thereby showing that the SS compounds have been reduced. In a parallel series of experiments, where the SS compounds were added to samples of latex dispersed in buffer and previously heated to 50° C for one hour, the increase in the SH content was markedly less.

TABLE III

Sample	Fresh latex		Latex heated prior to incubation	
	Initial titre	Increase in titre	Initial titre	Increase in titre
1	8.8	0.8	8.9	0.3
2	7.2	1.0	7.3	0.4
3	7.1	1.1	7.2	0.4

(4) Experiments with the press-juice from papaya fruit pulp—100 c.c. of the fresh juice from the pulp of papaya fruit were incubated with a solution containing SS compounds (2.5 per cent concentration) for 4 hours and the SH content estimated. In the control series, the juice was boiled prior to incubation. The results tabulated in Table IV show that there is a marked rise in the iodine titre indicating the presence of reducing systems in the juice. The thermolabile nature of the reducing systems is shown by the fact that this increase in titre becomes markedly less when the juice is heated prior to incubation.

TABLE IV

Sample	Time of incubation Hrs	Increase in titre c.c. N/100 iodine	
		Fresh juice	Heated juice
1	2	2.0	0.8
2	4	5.1	1.3
3	4	5.2	1.4
4	2	2.4	0.9
5	2	3.7	1.1
6	4	7.2	1.8
7	2	4.1	1.2
8	4	6.0	1.8

## II OXIDATION OF ASCORBIC ACID PRESENT IN THE LATEX.

Vitamin C exists along with the thiols in the latex. That glutathione affords protection against the oxidation of vitamin C by hexoxidase or copper was shown by Hopkins and Morgan.<sup>9</sup> The observations reported in this section of the paper support the main conclusions of Hopkins and co-workers.

(1) *Influence of aeration on the concentration of thiols and vitamin C of the papaya latex*—The lay-out of the experiments was exactly similar to that described in the earlier part of the paper. 5 gm latex were weighed out into each of 6 wash-bottles (300 c.c. capacity) and air bubbled through at intervals, the vitamin C (dye titration)<sup>10</sup> and SH concentrations were separately determined in aliquots of the trichloracetic acid extracts. The results are tabulated in Table V. The values for vitamin C and thiols are given in c.c. of N/100 iodine corresponding to 1 gm of latex.

TABLE V

Time (Hrs.)		0	$\frac{1}{2}$	1	2	4	6
Sample 1	Vitamin C	0.6		0.6	0.6	0.5	
	SH .	5.5		5.7	5.6	3.6	..
,, 2	Vitamin C	0.3	0.3	0.3	0.3	0.3	0.2
	SH .	5.4	5.2	5.3	5.1	3.3	2.6
,, 3	Vitamin C .	0.8	0.9	0.8	0.8	0.6	0.6
	SH .	9.3	9.5	9.6	9.6	7.0	5.1

(2) *Effect of preliminary heating of the latex on the course of oxidation of vitamin C and thiols*—The previous experiment was repeated with samples of latex dispersed in phosphate buffer and heated at 50°C for one hour prior to aeration.

TABLE VI

Time (Hrs.)		0	1	2	4	6
Sample 1	Vitamin C	0.6	0.6	0.6	0.5	0.3
	SH	5.5	4.0	4.1	2.1	0.5
,, 2	Vitamin C .	0.8	0.8	0.8	0.7	0.6
	SH .	6.1	5.0	3.5	2.3	1.0

(3) *Influence of thiol compounds of papaya latex on the oxidation of ascorbic acid by copper*—To 50 c.c. of a boiled aqueous extract of the latex was added pure crystalline ascorbic acid in solution (70 mg.) and aerated after adding a trace of copper. The vitamin C content as well as the concentration of the thiols were determined in aliquots at intervals of 10 minutes. Table VII gives the results obtained. The values for vitamin C and SH are given in terms of N/100 iodine. There is complete protection of ascorbic acid from oxidation by copper as long as there is even a small amount of the thiols present in the solution.

TABLE VII

Aeration time in mins	Vitamin C	SH
0	2.9	3.0
10	2.8	1.8
20	2.8	1.0
40	2.2	0.0
60	0.6	0.0

#### *Conclusions and Summary*

The presence in the latex, and more especially in the pulp of the papaya fruit, of a system responsible for maintaining the thiol compounds in the reduced condition is clearly established. Its thermolabile character is indicated by the observation that a preliminary heating of the latex dispersed in buffer or the press-juice from the pulp to a temperature of 50° C. for a period of 60 minutes, renders it inactive. The system present in the papaya, in these respects, is analogous to that in the liver described by Hopkins. Further work is called for in order to determine the exact nature of the mechanism.

The significance of this finding lies in the fact that the reducing system provides a regulating mechanism for the proteolytic processes in the plant, the concentration of the SH compounds which function as the natural activators of papain being conditioned by the activity of this system. It also helps, indirectly, to maintain the ascorbic acid present in papaya in the

reduced condition, as the thiol compounds afford complete protection to the vitamin against oxidation by hexoxidase or copper as previously shown by Hopkins, and confirmed by us.

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7. Kuhnau *Biochem Z*, 1931, **230**, 353
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9. Hopkins and Morgan *Biochem J* 1936, **30**, 1446
10. Birch, Harris and Ray *Ibid*. 1933, **27**, 590.

# ON THE DEVELOPMENTAL MORPHOLOGY OF ANDROGYNOUS RECEPTACLES IN *MARCHANTIA* *PALMATA* NEES\*

BY K S SRINIVASAN, B Sc (HONS), M Sc

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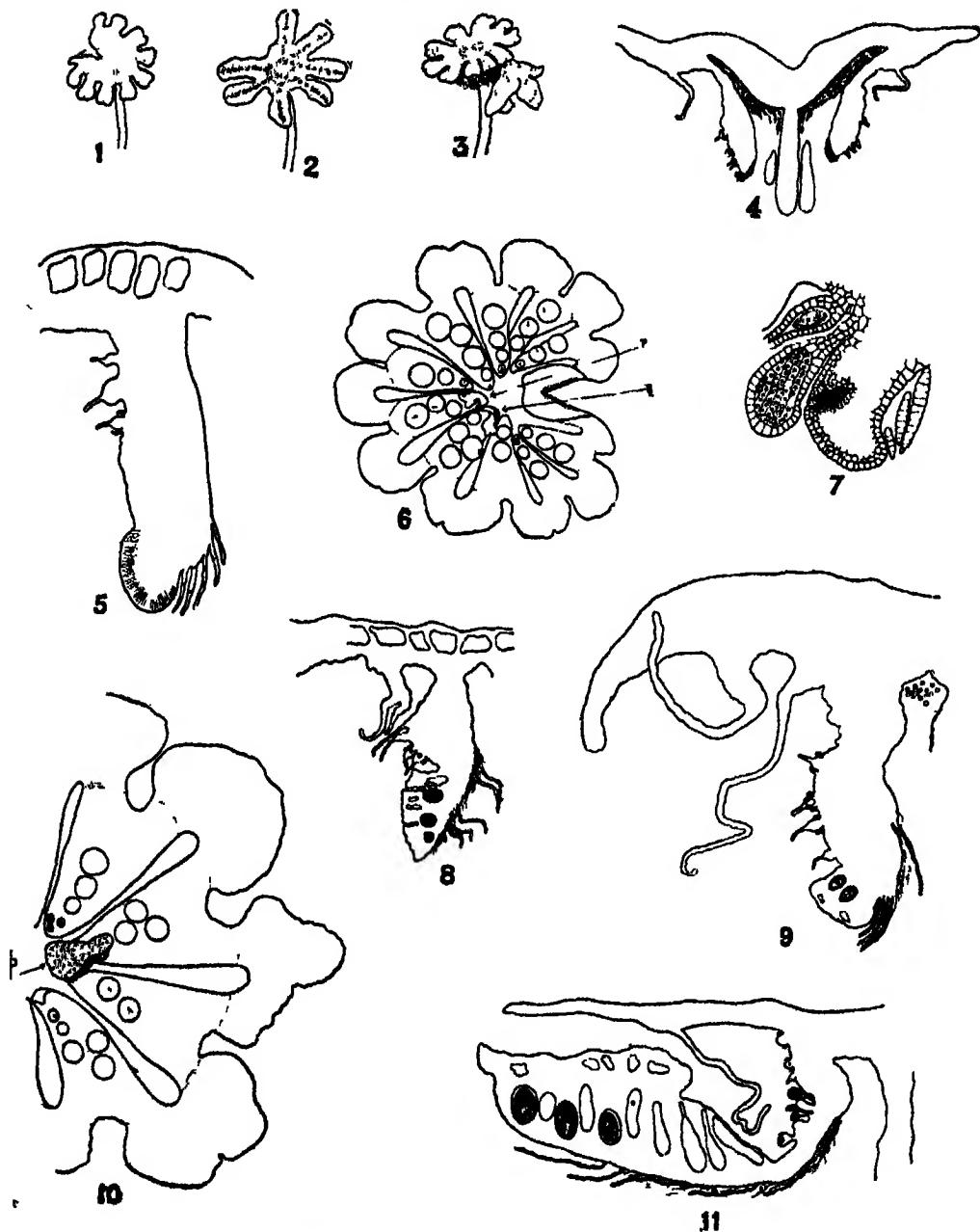
*Marchantia palmata* is a very common liverwort growing in plenty at Ootacamund on the Nilgiris. Most of the plants are female and bear plenty of archegoniophores. The male plants (Pl II, Fig 5c, Text-fig 2) are extremely few, being about only 1 per cent or less. In most cases, the female receptacles show one or more proliferations from their under surface (Pl II, Fig 5a, Text-fig 3). A section of these receptacles shows the usual archegonia on the underside as in all species of *Marchantia*, but a section of the proliferations shows, peculiarly enough, a large number of antheridia on them (Pl II, Fig 3). The receptacles in this *Marchantia* are thus bisexual and androgynous.

A detailed account of the androgynous receptacles of this Indian liverwort has not been published so far. The author took advantage of the large amount of material available at Ootacamund to make a detailed study of these receptacles.

It is not easy to get a correct idea of the nature of these proliferations with the aid of microtome sections alone, since their growth is generally somewhat curved and twisted. It was only after examining numerous hand sections along with the microtome sections of the proliferations in all stages of growth and also after careful examination with the aid of a Greenough Binocular dissecting microscope of both dissected and undissected material that a correct idea of the nature of the proliferations could be obtained.

The female receptacle is more or less disc-shaped with about 7 to 9 rays and measures 10 to 14 mm across (Text-fig 1). The upper surface is

\* From the University Botany Laboratory, Madras. This paper formed part of a Thesis submitted for the Degree of Master of Science of the University of Madras. It was read before the Annual Meeting of the Indian Academy of Sciences at Madras on 20th December 1938.



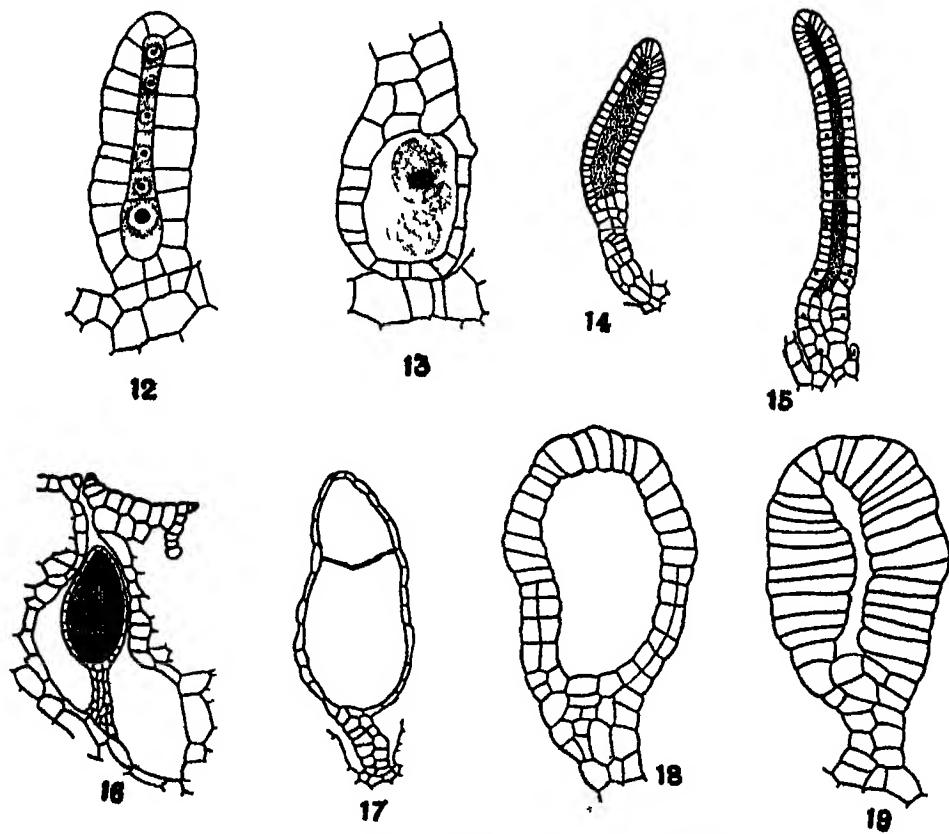
TEXT-FIGS 1-11 *Marchantia palmata* Nees

- (1) A normal female receptacle  $\times 1.5$
- (2) A normal male receptacle  $\times 1.5$ .
- (3) An androgynous receptacle showing the proliferations growing from its under

- side  $\times 1.5$ . (4) A median vertical section of a normal female receptacle  $\times 7.5$ .  
 (5) Beginning of the proliferation  $\times 22$  (6) Ventral view of the bisexual receptacle with the velum and the perianth dissected out, showing the end of two female branches beginning to grow out as proliferations  $P_1 P_2 \times 4$  (7) A section through a proliferation showing an exerted antheridium by the side of an archegonium  $\times 96$ .  
 (8) & (9) Later stages in the growth of the proliferation (8)  $\times 13$  (9)  $\times 18$ .  
 (10) Same as Fig 6, but with the proliferation ( $P$ ) grown out a little more.  $\times 7.5$ .  
 (11) A well-grown proliferation  $\times 11$

smooth and dome-shaped with or without a slight depression in the centre. A number of archegonia is formed on each branch of the receptacle, and a large number of the sporogonia develops to maturity. Each group of archegonia is well protected by the pronounced development of the velum which passes round the growing point also. Only when the velum is removed by careful dissection can the growing point be seen clearly. At first there is no indication of any proliferation from the female branch. Each lobe of the receptacle bearing the archegonia, as in all species of *Marchantia*, is bent downwards, the growing point being directed towards the stalk of the receptacle. In the Nilgiri *Marchantia*, the lobe does not grow adpressed to the ventral surface of the dome-shaped portion of the archegoniophore, but grows a little free from it and is somewhat pendant (Pl II, Fig 4, Text-fig 4). The apical portion of the branch bearing the archegonia, instead of ceasing its growth after forming a certain number of archegonia as in the other species of *Marchantia*, becomes active again and grows into a small cushion-like structure (Text-fig 5). This structure continues to grow forward and downward and forms a short, more or less pendant, tongue-like outgrowth (Text-figs 8, 9, 10). At first, the proliferation is made up of a solid mass of uniform cells (Text-fig 5), but later on air-chambers with assimilating filaments are developed in it (Text-fig 9) and the proliferation continues to grow gradually outwards and upwards and at the same time turns on its axis as it were about  $180^\circ$  or so and finally brings the morphologically dorsal side to the upper side (Text-figs 8, 11). It then continues to grow into a flat green narrow lobe. This outgrowth is somewhat narrow below but becomes gradually broader towards its apical portion. As it grows, it goes past the velum, which then appears as if attached to its flanks. Very frequently, it may branch dichotomously into two spreading lobes which may also occasionally divide a second time dichotomously (Pl II, Fig 5 a). Fully grown proliferations show a certain amount of resemblance to the lobes of a normal antheridiophore. Their ventral surface bears amphigastria in definite rows together with tufts of rhizoids. The amphigastria are produced rather early in the development of the proliferation (Text-figs 5, 8, 9, 11).

Sections of these proliferations show a number of antheridia sunk in cavities on the upper side. But very often the first antheridium that is formed is not sunk in any cavity, but is situated just on the surface like an archegonium and is not surrounded by any tissue (Pl II, Figs 3, 6, Text-fig 7). These exerted antheridia show a certain amount of resemblance to archegonia in that their walls are elongated radially (Text-fig 19) as in archegonia or are made up of two layers near the base as in the venter region of the archegonium (Text-fig 18) The later formed antheridia grow in an acropetal manner with the youngest near the apical and the



TEXT FIGS 12-19 *Marchantia palmata* Nees

(12) A normal archegonium  $\times 713$  (13) An abnormal archegonium with three eggs.  $\times 846$ . (14 & 15) Abnormal antheridia (14)  $\times 87$  (15)  $\times 97$  (16) A normal antheridium.  $\times 55$ . (17) An antheridium with two chambers  $\times 63$  (18) Abnormal antheridium showing division of the cells of the wall-layer towards the basal region.  $\times 267$ . (19) Abnormal antheridium showing the cells of the wall-layer elongated at right angles to the axis of the structure.  $\times 170$ . Contents not shown in Figs. 17-19.

oldest near the basal region. Most of the antheridia that are formed later are normal and quite similar to those formed on normal male receptacles. But the few antheridia that are formed on the proliferation near its base are very peculiar in showing characters which are midway between those of antheridia and of archegonia. Most of these resemble archegonia in external shape, but contain inside a large number of spermatogenous cells (Pl. II, Figs 2, 6, Text-fig 15). These spermatogenous cells are invariably found in a degenerate and aborted condition. A few are very similar to antheridia in general structure but their upper portion is not broad and rounded as in normal antheridia but are very narrow as in archegonia (Text-fig 14).

An interesting case of an abnormal archegonium was found in one of the sections. This archegonium contained three eggs in the ventral region and, out of these three, two were large and one was very small (Text-fig 13). This case suggests a tendency on the part of the cells inside the archegonium to multiply in number.

One of the abnormal antheridia had a long and slender stalk, but the antheridial portion was divided into two compartments by the development of a partition-wall right across the antheridium (Text-fig 17). The chambers were empty and presumably contained spermatogenous cells. The significance of this was not clear. It is just possible that the two chambers represent the development of the venter and the neck region of an archegonium and were brought about by the division of the cells in these two respective portions.

The proliferations during their growth would appear to start as a definitely female structure, but to gradually change to a male structure. And, during the stages of this transition, it forms sexual structures which are intermediate between female and male.

#### *Discussion*

Androgynous receptacles have been recorded in a few genera of the Marchantiaceae (*Preissia*, *Dumortiera* and *Marchantia*) by various authors\*. As early as 1834, Taylor<sup>14</sup> recorded androgynous gametophores in *Dumortiera irrigua*. In a later communication<sup>15</sup> as regards the gametophores of this plant he states that "The fructification is commonly dioecious, sometimes monoeious, and not rarely androgynous as observed in *Marchantia androgyna*".

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\* A short historical account of androgynous receptacles is given by Cutting<sup>8</sup> and A. W. Haupt.<sup>9</sup>

In 1880, Goebel<sup>6</sup> described androgynous receptacles in *Preissia commutata*. He observed that in these receptacles the two anterior lobes bore antheridia on the upper surface, while the two posterior ones had archegonia on the lower surface. He thinks that this does not represent a reversion to the primitive monococious arrangement of the sexual structures, but is merely a case of replacement. In 1881, Leitgeb<sup>13</sup> also recorded androgynous receptacles in *Preissia commutata*. These receptacles, unlike those recorded by Goebel, bore two archegonial groups on the lower surface of the anterior portion, while the posterior portion bore antheridia on the upper surface. He expresses the view that the androgynous condition is brought about by a delayed sexual differentiation of the branches that bear the sexual structures, instead of such a change being initiated earlier in the vegetative portion of the thallus itself. In 1899, Townsend<sup>14</sup> described androgynous receptacles in the same liverwort. These receptacles bore antheridia on the upper side and archegonia on the under surface. A W Haupt<sup>7</sup> states that the receptacles of *Preissia quadrata* are very frequently bi-sexual. Some of them were like those described by Leitgeb and others were like the ones observed by Goebel. He states that in most cases "either both anterior groups of sex organs were of one sex and both posterior groups of the other sex, or less frequently three were of one sex and one of the other. In a few cases both of the groups on one side of the receptacle were of the same sex, and both groups on the opposite side of the other sex". O'Hanlon<sup>15</sup> in his paper on *Preissia quadrata*, gives a photomicrograph of a longitudinal section of an androgynous receptacle, in which the arrangement of the antheridia and archegonia were quite similar to that of Haupt's specimens. He states that "*Preissia* is not only a monococious plant, but there also occur mixed heads".

Ernst<sup>8</sup> recorded androgynous receptacles in *Dumortiera trichocephala* and *D. velutina*. He found that these receptacles were fairly common in the former, but were found only very occasionally in the latter. In these receptacles, one portion was completely male and bore antheridia on the upper side and the other portion was completely female and formed archegonia on the under side. Campbell<sup>1</sup> also found bisexual receptacles in *Dumortiera trichocephala* and states that they were quite similar to those found by Ernst. Kashyap<sup>11</sup> states that androgynous receptacles occur frequently in *Dumortiera hirsuta*, especially in forms collected from very moist places, but does not give details regarding their structure.

Heberlein<sup>9</sup> found in an unnamed species of *Marchantia* from Peruvian Andes, two androgynous receptacles which had much the shape of the female receptacles and had the archegonia on the under side in their

usual position, but had antheridia on its upper side sunk in cavities G Haupt<sup>8</sup> found in *Marchantia grisea* that the receptacles were either male or hermaphrodite In the bisexual ones one portion of the receptacle was male and the other female Cutting<sup>9</sup> found in a species of *Marchantia* which he got from Chelsea Physic Gardens, London, plenty of androgynous receptacles These receptacles resembled archegoniophores But a number of proliferations were growing from their lower surface And on these proliferations were formed a number of antheridia sunk in cavities He states that these antheridia-bearing proliferations are "formed as out-growths from a portion of the under surface of a female branch" He again states that the "male outgrowth was formed secondarily as a kind of proliferation, and is not a mere replacement of the normally female branch". He suggests that "it would not be unlikely for the entire archegonia-bearing portion of a branch to grow out into a protuberance", but states, however, that "no such case has been seen" by him Chopra<sup>10</sup> refers to some receptacles of *Marchantia indica* as androgynous and says that they are quite similar to those described by Cutting

Now, coming to the Nilgiri *Marchantia*, we find that its receptacle is primarily an archegoniophore and its general form and course of development are quite like that of any normal female receptacle But the archegonia-forming lobes of the receptacle, after producing the usual output of female structures, instead of stopping further growth, become active once again and grow out into antheridia-bearing proliferations These proliferations produce at first, however, sexual structures which are intermediate in character between an archegonium and an antheridium and only later on do they produce typical antheridia So we see that Cutting's suggestion that "it would not be unlikely for the entire archegonia-bearing portion of a branch to grow out into a protuberance" is now actually found very commonly in the Nilgiri *Marchantia*, though Cutting did not find any such case in the Chelsea material

In all the previous cases mentioned above, the receptacles are androgynous from the very commencement Some portions of them form the male structures and the other portions the female structures The archegonia and the antheridia are situated on the main receptacle itself, though their positions varied in the different forms But the present case is quite different from any of the previously recorded types Here the whole receptacle is completely female to start with and produces only archegonia up to a certain stage After that, some of the archegonia-forming lobes become transformed into antheridia-forming ones In other words, the lobes change their sex from female to male during the course of their development. The

difference between the previously recorded cases and the present one is this In all the previous cases the receptacle is bisexual from the very commencement, some portions being male and the others female, whereas in the present case the receptacle is unisexual (female) to start with and then in its ultimate portions changes its sex from female to male

What exactly may be the cause which leads to this change of sex is not quite clear It may be mentioned in this connection that a large number of plants bearing these androgynous receptacles are infected with a fungus The vegetative portion of the thallus is very heavily infected in almost all cases In a few cases the mycelium was found to invade the receptacle and to attack the sexual structures also This fungus produces on the dorsal surface of the receptacle and on the proliferations a number of small pycnidia (Pl II, Fig 1) I am unable to say at present whether this fungus could in any way be the cause of the change of sex in the present *Marchantia*

G Haupt,<sup>8</sup> while investigating the androgynous receptacles of *Marchantia grisea*, found that the male plant had only 9 chromosomes whereas the female and the hermaphrodite ones had 10 chromosomes, of which one was very small and was called by him the "z" chromosome But the antheridia formed by these hermaphrodite plants had only 9 chromosomes He thinks that, during the formation of these antheridia, the "z" chromosome is somehow lost This "z" chromosome is considered by him as being responsible for the female sex In the Nilgiri *Marchantia* the author found plenty of aberrations in the chromosome complement of the normal female receptacle as well as of the proliferations It could not be decided how far these aberrations may be responsible for the change of sex in the liverwort A detailed account of these aberrations will form the subject of a separate communication

A word may be said here regarding the change of sex in the Nilgiri *Marchantia* The change of sex of the branch forming the archegonia is, as seen already, not sudden Before it begins to form normal antheridia, it forms structures intermediate between antheridia and archegonia The change in the sex is gradual A study of these abnormal antheridia brings prominently to view the homologous nature of the two structures, viz., the antheridia and the archegonia Both these structures represent gametangia enclosing sexual cells or gametes within a common wall In the male structures are found quite a large number of sexual cells all of which are functional, while in the female are found only a small number of sexual cells of which only one (egg) is functional Davis<sup>4</sup> suggests that antheridia

and archegonia are derived from a common sporangial structure Holferty<sup>10</sup> found in *Mnium cuspidatum* plenty of abnormal archegonia which showed structures intermediate between those of an antheridium and of an archegonium. From a consideration of these, he comes to the conclusion that antheridia and archegonia had a common origin, probably from a multicellular sporangial structure, as suggested originally by Davis. The various intermediate sexual structures found in the Nilgiri *Marchantia* would also appear to lend much support to this view.

### Summary

1 *Marchantia palmata* which grows commonly at Ootacamund on the Nilgiris forms plenty of androgynous receptacles.

2 These receptacles start as purely female receptacles, but soon one or more proliferations bearing antheridia grow out from its under surface.

3 These proliferations are merely the archegonia-bearing lobes of the female receptacle which become active again and continue to grow further into narrow elongated outgrowths.

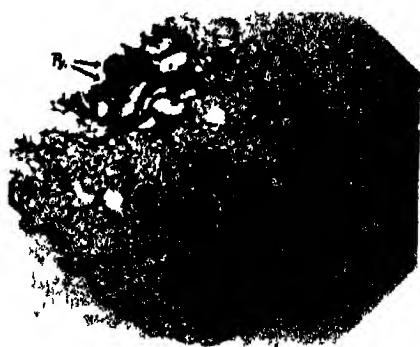
4 The proliferations produce at first sexual structures which are intermediate between an archegonium and an antheridium and later on typical antheridia. A consideration of these intermediate structures suggests that antheridia and archegonia are homologous structures.

5 A fungus forming pycnidia is generally present in the liverwort. It could not be decided whether the change of sex in the receptacle is due to this fungal attack.

I have great pleasure in acknowledging my indebtedness to Prof M O P Iyengar, M.A., Ph.D. (Lond.), F.L.S., for his constant guidance and help in the preparation of this paper. My thanks are also due to the authorities of the University of Madras for the award of a research scholarship, during the tenure of which the present investigation was carried out.

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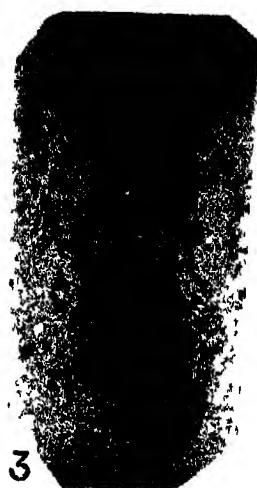
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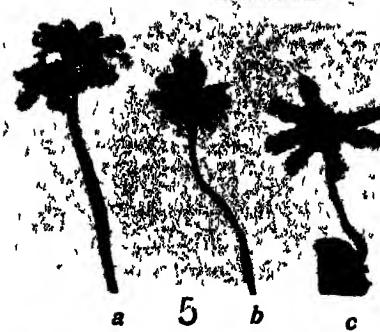
2



3



4



a

b

c



6



7

*Marchantia palmata* Nees



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### EXPLANATION OF PLATE II

#### *Marchantia palmata* Nees

- Section of a proliferation showing a portion (darkly stained portion) attacked by a fungus. Note the pycnidia (py) of the fungus  $\times 25$ .
- Section of a proliferation showing an abnormal antheridium by the side of a normal one  $\times 38$
- Tangential section of a proliferation showing a superficial antheridium at base, and a number of normal antheridia higher up  $\times 35$
- Vertical section of a normal female receptacle  $\times 9$
- Photographs of a bisexual (a), female (b) and male (c) receptacles  $\times 3$
- Proliferation showing two abnormal antheridia one superficial and the other inside a cavity  $\times 24$ .
- Longitudinal section of a proliferation showing antheridia inside chambers. Note the archegonia in their original positions in Figs 6 and 7  $\times 36$

## BRYOZOA FROM THE BAGH BEDS

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(Communicated by Prof L Rama Rao, M.A., F.G.S.)

### Introduction

IN the preliminary identification of the fossils from the Bagh Beds given by Duncan,<sup>1</sup> the Bryozoa were represented by *Eschara* sp., and *Escharina* sp., in the Deola-Chirakhan Marl. To this P N Bose added *Ceropora dispar* Stoliczka, a species described from the Ariyalur stage of the Cretaceous series of South India.<sup>2</sup> But like all the other groups of fossils from these strata Bryozoa also were till now not studied in any detail. Subsequent to the study of the *Echinoids* and *Rhynchonellids* from this formation,<sup>3</sup> the Bryozoa were taken up for a detailed study with a view to investigating into the alleged faunal affinities between the Bagh Beds and the Cretaceous series of South India,<sup>4</sup> and to see what light they throw on the problem of the age of the Bagh Beds.

The material studied here was collected by the late Prof K K Mathur and by the present writer from the various exposures in the neighbourhood of Agarwara (lat 22° 16', long 75° 59'), Chirakhan (lat 22° 21' 30", long 75° 7' 30"), the type locality, Ajantar (lat 22° 19' 30", long 74° 55') and Bagh (lat 22° 21' 30", long 74° 47' 30") Though the Bryozoa described below were obtained from all the fossiliferous divisions of the Bagh Beds,<sup>5</sup> their main bulk comes from the Coralline Limestones which are very largely made up of their fragments. Due to the unusually hard nature of the Coralline Limestone and its saccaroidal appearance on the freshly broken surface, it is only on the naturally weathered surfaces that these fossils can be observed, the fragments weathered out from the Coralline Limsetone always get mixed up with those from the Deola-Chirakhan Marl, the staining red due to iron oxide is more conspicuous in the case of the specimens from the Marl, but here the nature of the matrix

<sup>1</sup> Q J G.S., 21, 351; Mem. Geol. Ind., 250.

<sup>2</sup> Mem. G.S.I., 21, 37, 40, 47; Pal. Ind., (8), 2, 26, pl. 3, fig. 1-3; Mem. Geol. Ind., 250.

<sup>3</sup> Proc. Ind. Acad. Sci., (B), 6, 60-71; ibid., 7, 300-10; ibid., 9, 236-46

<sup>4</sup> Mem. G.S.I., 21, 38-44

<sup>5</sup> Ibid., 21, 35-44; Curr. Sci., 4, 322.

has not always proved to be a dependable indication for the source of the fossil, and thus one is oftentimes very much uncertain as to the exact occurrence and the relative abundance of the different species in the Marl and in the Coralline Limestone. Owing to this unfavourably hard nature of the rock, the method of washing and screening which is oftentimes applicable for securing isolated Bryozoan specimens, is found to be absolutely useless in the present case. Thus, besides the inherent difficulty in studying fossil Bryozoa has, very seriously hampered the present work. It is only in the three species of *Ceropora* that isolated specimens were obtained from among the debris of the weathered Coralline Limestones, and only their internal structure could be studied under the microscope in thin sections taken along definitely known directions. In all the other species a large amount of material could be examined only on the weathered surfaces of rock specimens, their longitudinal and transverse sections being obtained accidentally in rock sections.

The author very much regrets that due to weathering and the hard intractable material encrusting the fossils, the photomicrographs could not be better than what are reproduced here.

All the Type specimens are preserved in the Department of Geology, Benares Hindu University

#### *Description of Species*

Order	Cyclostomata, Busk
Family	<i>Idmoniidae</i> , Busk
Genus	<i>Idmonea</i> Lamouroux, 1921

#### *Idmonea biserialis* sp. nov

(Plate III, Figs 2, 9)

	mm
Dimensions — Outer diameter of the Zoacium	0 15
Inner .. ..	0 10

*Description* — The zoarium is branching dichotomously, the apertures are arranged in oblique alternating series on the right and the left, apertures are moderately projecting outwards and sub-circular in outline.

*Comparison* — This species closely resembles *Idmonea francorum* Pergens,<sup>6</sup> from the Senonian of Central France, in which, however, the zoacia are a little contracting towards the aperture and thus have smaller apertural diameter.

<sup>6</sup> Bull. Soc. Belg. Géol., 3, 348, pl. 13, fig. 1.

In *Idmonea controtilis* Lonsdale<sup>7</sup> from the Senonian of New Jersey, Charente, France, and Pooland, South Africa, the zoacia are without any definite arrangements, the upper part of the zoacia is free and much projecting outwards

Family            *Ceriporidæ*, Busk  
 Genus            .     *Ceripora* Goldfuss, 1827  
*Ceripora dimorphopora* sp. nov  
 (Plate III, Fig. 5, Plate IV, Figs. 2-3)

	mm
<i>Dimensions</i> — Longer diameter of larger aperture	0 16
Shorter        "        "        "	0 10
Longer diameter of smaller aperture	0 9
Shorter        "        "        "	0 6

*Description* — The zoarium is large, free, sub-cylindrical with lateral branches, the surface has sometimes feebly developed tuberosities. The zoacial tubes are polygonal with rather thick walls. The apertures are rather small, elliptical and in two sizes, the larger apertures are often surrounded by the smaller ones, the larger apertures are more or less regularly arranged in quincunx. In general the surface shows a heteroporid aspect. The zonal lines are not much separated.

*Comparison* — By the nature of the zoarium this species resembles *Ceripora lobifera* Canu and Bassler,<sup>8</sup> from the Valangian of Sainte-Croix, Switzerland, from which it can be easily distinguished by its elliptical apertures in two sizes and much thicker zoacial walls.

From *Ceripora dimorphocella* Canu and Bassler,<sup>9</sup> from the Aptian of Farringdon, England, this species can be distinguished by its elliptical orifices and the zonal lines.

*Ceripora conoformis* sp. nov  
 (Plate III, Fig. 3, Plate IV, Figs. 1, 5)

	mm
<i>Dimensions</i> — Longer diameter of the larger aperture	0.17
Shorter        "        "        "        "        "	0.12
Longer diameter of the smaller aperture	0.10
Shorter        "        "        "        "        ..	0.6

*Description* — The zoarium is conical with no lateral branches; the general surface gives a heteroporid appearance. The zoacial tubes are

<sup>7</sup> Q.J.G.S., 1, 68, Pal. Fr., 5, 729; Prod. Pal. Strat., 2, 265, Ann. S. Afric. Mus., 4, 286.

<sup>8</sup> Proc. U.S. Nat. Mus., 67, 27, pl. 23, figs. 11-17.

<sup>9</sup> Ibid., 29, pl. 24, figs. 1-6, pl. 31, figs. 7-8.

polygonal with the walls rather thick. The apertures are small, elliptical and generally in two sizes. The larger apertures are surrounded by the smaller ones and are generally arranged in a roughly quincunxial order. Not infrequently are found apertures of a third size roughly intermediate between the two sizes, of which the micrometric measurements are given above. In the case of such apertures the zoacial walls are found to be thicker than in the case of others, so that this third size of apertures is in reality a modification of the larger ones.

*Comparison*—This species is distinguished from the associated *C. dimorphopora* sp. nov., described above, by its conical zoarium without lateral branches, the zonal lines more frequent and the occasional development of the third size of apertures by thickening of the zoacial walls.

*Ceriopora ellipsopora* sp. nov  
(Plate III, Fig. 6, Plate IV, Fig. 4)

	mm	mm
Dimensions — Longer diameter of the orifice	0 16	— 0 19
Shorter     "         "	0 9	— 0 11

*Description*—The available material is in the form of cylindrical pieces over 15 mm in length, so that it is uncertain whether it has a tendency to branching laterally. The cross-section of zoarium is broadly elliptical. The zoacial tubes are polygonal with rather thick walls. The orifices are elliptical and arranged roughly in hexagonal pattern in such a way that every orifice is at the centre of a hexagon.

*Comparison*—This species differs from the associated *C. dimorphopora* sp. nov., described above, by the nature of its zoarium, only one type of zoacia, and zonal lines rather crowded in the marginal region.

*Ceriopora dispar* Stoliczka<sup>10</sup> from the Ariyalur Stage of the South Indian Cretaceous Series which Bose<sup>11</sup> had reported to be present in the Bagh Beds also, can be easily distinguished from the present species by its more or less circular and smaller orifices.

*Ceriopora lobifera* Canu and Bassler<sup>12</sup> from the Valangin of Switzerland differs from this species in having branching zoarium with oval to sub-circular apertures and thinner zoacial walls.

Family . . . *Ceriocavidae* Canu and Bassler  
Genus .. . *Ceriocava* d'Orbigny, 1858

<sup>10</sup> Proc. U.S. Nat. Mus. 67, 29, pl. 24, figs. 1-8, pl. 31, figs. 7-8

<sup>11</sup> Pal. Ind., (8), 4, pt. 2, 26, pl. 3, figs. 1-3, Ann. Pal., 11, fasc. III-IV, 27, pl. 11, fig. 3; Cat. Cret. Bry., 1, 251.

<sup>12</sup> Mem. G.S.I., 21, 37, 41, 48.

*Ceriocava micropora* sp nov

(Plate III, Fig 1)

	mm	mm
<i>Dimensions</i> —Diameter of the orifice	..	0 10
Diameter of a large branch	.	2 3

*Description* —The zoarium is free and branching with the branches cylindrical. The orifices are rather small, polygonal, arranged in quincunx, but occasionally roughly in horizontal lines also. The ovicells are very minute.

*Comparison* —This form resembles the Valangian species *Ceriocava grandipora* Canu and Bassler<sup>13</sup> from Switzerland. The orifices in the present species are, however, very much smaller (*i.e.*, about one-third of those of the Swiss species).

Order	Ciliostomata, Busk
Family	Membraniporidae, Busk
Genus	<i>Membranipora</i> Blainville, 1834

*Membranipora mathuri\** sp nov

(Plate III, Fig 10)

	mm
<i>Dimensions</i> —Longer diameter of zoacium	0 27
Shorter     ,,     ,,	0 19
Longer diameter of aperture	0 22
Shorter     ,,     ,,	0 13

*Description* —The available specimens are preserved as small patches each including only a few zoacia. The zoacia are arranged in more or less regular linear series, those of the adjacent series being nearly in horizontal lines. The series have a common suture. The zoacia are oval to sub-elliptical, the apertures are oval. The zoacia are bordered by a more or less distinct rim.

*Comparison* —*M. vendinensis* d'Orb<sup>14</sup> from the Cenomanian of Sarthe, France, is closely related to this species, but the French form has larger zoacia and the disposition is less regular.

*M. sub-ovalis* Canu<sup>15</sup> from the Senonian of Tunis has the zoacia of the same type and disposition as the present species, but the African form has its zoacia larger and also has interzoacial pores.

<sup>13</sup> Proc. U.S. Nat. Mus., 67, 67, pl. 9, figs. 14-17.

\* This species is named after the late Prof. K. K. Mathur.

<sup>14</sup> Prod. Pal. Strat., 2, 174; Pal. Fr., 5, 545, pl. 600, figs. 9-10, Bull. Soc. Géo. Fr., (4), 12, 349, pl. 18, fig. 1, *ibid.*, (3), 28, 354; *ibid.*, 25, 741.

<sup>15</sup> *Ibid.*, (1), 3, 680, pl. 21, fig. 2.

*Membranipora pseudo-normaniana* sp. nov

(Plate III, Fig. 8)

	mm	mm
Dimensions — Longer diameter of zoacium	0 23	
Shorter " "	0 20	
Longer diameter of aperture	0 15	— 0 17
Shorter " "	0 10	— 0 12

**Description** — The zoaria are preserved as small patches, the zoacia are disposed irregularly and polygonal in outline, the spaces between larger zoacia are occupied by smaller ones which are probably due to overthickening of the zoacial wall of the larger ones. The aperture is oval to sub-elliptical in outline and is nearly half of the zoacium in diameter.

**Comparison** — This form resembles very closely *M. normaniana* d'Orb<sup>16</sup> from the Senonian of France and North-West Germany, but the European species has wider apertures and the zoacial walls thinner.

*M. cervicornis* Brydone<sup>17</sup> from the *B. mucronata* zone (Senonian) of Portsdown, England, has its orifices wider and more sub-circular and the walls relatively thinner.

Family              Onychocellidae, Jullien  
 Genus              *Eschara* Lamarck, 1801

*Eschara chirahanensis* sp. nov

(Plate III, Fig. 7)

	mm
Dimensions — Length of the zoacium	0 36
Width " "	0 22

**Description** — The zoarium is encrusting on rhynchonellid shells, with the zoacia arranged in regular linear series, the zoacia of the adjacent series alternating. The aperture is oval with a low simple border which is clearly seen on the anterior and on the two sides, aperture is nearly half of the zoacium in length.

**Comparison** — This species can be distinguished from *E. cenomana* d'Orb<sup>18</sup> from the Cenomanian of France, by its encrusting habit, larger zoacia and the front wall and the aperture relatively a little narrower.

<sup>16</sup> *Prod. Pal. Strat.*, 2, 262, *Pal. Fr.*, 5, 530, pl. 607, figs 5-6; and 9-10, 551, pl. 607, figs 11-12. *Leopoldiana*, 127, pl. 5, fig. 2.

<sup>17</sup> *Geol. Mag.*, (5), 10, 198, pl. 7, figs 3-4.

<sup>18</sup> *Prod. Pal. Strat.*, 2, 170, *Pal. Fr.*, 5, 107, pl. 602, figs 1-3, 246, pl. 687, figs 14-16; *Bull. Soc. Géol. Fr.*, (3), 25, 737; *ibid.*, 28, 361; *ibid.*, (4), 12, 353, pl. 14, figs 3-4.

The present species differs from *E. santonensis* d'Orb.<sup>19</sup> from the Senonian of France, in having a larger and more oval aperture.

*Eschara regularis* sp. nov

(Plate III, Fig. 4)

	mm
Dimensions — Longer diameter of zoacium	0 37
Shorter " "	0 25
Width of aperture "	0 12
Height of aperture "	0 10

**Description** — The zoarium is encrusting, the zoacia are hexagonal, longer than broad and arranged in regular series with zoacia of the adjacent series alternating, they are provided with a raised prominent rim. The front wall is feebly convex towards the middle and is much below the level of the zoacial rim. The aperture is nearly semi-circular with a low rim slightly broader than high, anteriorly rounded, posteriorly straight and rather large, it is situated just below the zoacial rim, which is closely followed by a very feeble, shallow depression after which the convexity of the front wall begins.

**Comparison** — As compared to *E. roiana* d'Orb.<sup>20</sup> from the Senonian of France and Pondoland, South Africa, the present species is an encrusting form with slightly broader zoacia.

*E. parisensis* d'Orb.<sup>21</sup> from the Senonian of the Paris basin, resembles the present species in having a depressed groove along the inner side of the zoacial rim and the regularity of disposition of the zoacia. The difference, however, lies in the present species having shorter zoacia and the aperture posteriorly straight and situated quite anterior to the centre of the zoacium.

By the irregularity of disposition and shape of the zoacia and the oval aperture with a tooth near its anterior margin *E. nereis* d'Orb.,<sup>22</sup> a Senonian species from Central France, can be easily distinguished from the present species.

<sup>19</sup> *Pal. Fr.*, 5, 100, pl. 603, figs. 1-8; pl. 678, fig. 4, *Prod. Pal. Strat.*, 2, 264; *Bull. Soc. Géo. Fr.*, (3), 28, 308.

<sup>20</sup> *Prod. Pal. Strat.*, 2, 264; *Pal. Fr.*, 5, 108, pl. 602, figs. 12-18, pl. 678, figs. 2-3; *Rev. Zool.*, 112, *Ann. S. Afric. Mus.*, 4, 280, *Bull. Soc. Géo. Fr.*, (3), 28, 300.

<sup>21</sup> *Rev. Zool.*, 112, *Prod. Pal. Strat.*, 2, 264; *Pal. Fr.*, 5, 110, pl. 603, figs. 4-6, pl. 678, figs. 5-6, *Bull. Soc. Géo. Fr.*, (4), 2, 13.

<sup>22</sup> *Rev. Zool.*, 112, *Prod. Pal. Strat.*, 2, 264; *Pal. Fr.*, 5, 111, pl. 603, figs. 10-18; pl. 604, figs. 1-4; pl. 678, fig. 7, *Bull. Soc. Géo. Fr.*, (3), 28, 391.

*Eschara holkari\** sp. nov

(Plate III, Fig. 11)

	mm
Dimensions — Longer diameter of zoacium . . .	0.3
Shorter " "	0.2

*Description* — The zoarium is encrusting, the zoacia are elliptical, arranged in regular linear series, with the zoacia of the adjoining series alternating with each other. The aperture is rather large, sub-circular to oval, a little more than half the size of the zoacium and has an inconspicuous rim, the front wall is depressed towards the aperture. The space in the interzoacial corners is trigonal and depressed.

*Comparison* — *E. dejanira* d'Orb<sup>23</sup> from the Senonian of the Paris-Pyrreneese basin differs from the present species in having the zoacia oval rather than elliptical, the aperture smaller and posteriorly slightly truncated and the marginal rim incomplete.

*Geological Age and Faunal Affinities*

The accompanying table summarises the faunal affinities of the Bryozoa from the Bagh Beds with those from other parts of the world. Since there are no species common to these beds and Cretaceous series of strata elsewhere, of which the geological horizon is fixed on the basis of other fossils, it is rather difficult to assign any definite horizon to these Bryozoa with certainty. However, to discuss their relations with species from different parts of the world, we find that these Bryozoa show, like the Echinoids from these beds,<sup>24</sup> a mixture of affinities towards certain European species ranging from the Valangian to the Senonian. Of the ten species described above, to consider first the more abundant ones, we have *Membranipora mathuri*, *M. pseudo-normaniana*, *Eschara Chirakhanensis* and *E. regularis*. Of these *Membranipora mathuri* is related to *M. vendinensis* d'Orb from the Cenomanian of Sarthe, *Eschara Chirakhanensis* is allied to *E. santonensis* d'Orb from the Senonian of France on the one hand and to *E. cénomana* d'Orb from the Cenomanian on the other, while the remaining two species have their allies in the Senonian of France. Among the less abundant forms, we have the three species of *Ceriopora* related to lower Cretaceous

\* This species is named after His Highness The Maharaja Holkar in whose territory the Bagh Beds are nicely exposed in the type sections at Chirakhnum.

<sup>23</sup> *Pal. Fr.*, 5, 161, pl. 675, figs. 17-19; *Bull. Soc. Géo. Fr.*, (3), 28, 401, pl. 6, figs. 15-16.

<sup>24</sup> *Proc. Ind. Acad. Sci.*, 6, 60-71, *ibid.*, 9

*Table showing Vertical Distribution and Affinity-Relations of the Bryozoa from the Bagh Beds*

No	Species from the Bagh Beds	Allied species with stratigraphical position	No-fusular Limestone	Flower Coralline Limestone	Deola Chirakhan Marl	Upper Coralline Limestone
1	<i>Idmonea biserialis</i> sp nov	<i>Idmonia frumentorum</i> Pergens, Senonian of France		X	*	X
2	<i>Ceripora lunulifera</i> sp nov	<i>Ceripora dimorphocella</i> Canu and Bassler, Apitan of Furington		X	*	X
3	<i>C. coniformis</i> sp nov	Do		X		X
4	<i>C. ellipsopora</i> sp nov	<i>C. lobifera</i> Canu and Bassler, Valangian of Switzerland				X
5	<i>Ceriocava micropora</i> sp nov	<i>Ceriocava grandipora</i> Canu and Bassler, Valangian of Switzerland				X
6	<i>Membriaspis mathuri</i> sp nov	<i>Membranipora vendinnen sis</i> d'Orb., Cenomanian of Sarthe		X	*	X
7	<i>M. pseudo norman tana</i> sp nov	<i>M. normaniana</i> d'Orb., Senonian of France	X	X	X	X
8	<i>Eschara chirakhanensis</i> sp nov	<i>Eschara senlonensis</i> d'Orb., Senonian of France & <i>E. Cenomana</i> d'Orb., Cenomanian of France	X	X	X	X
9	<i>E. regularis</i> sp nov	<i>E. parvula</i> d'Orb., Senonian of Paris basin		X	X	X
10	<i>E. holkari</i> sp nov	<i>E. dejarnae</i> d'Orb. Senonian of Paris-Pyrenees basin		X		X

species from Switzerland and Farringdon. *Ceriocava micropora* is allied to *C. grandipora* Canu and Bassler from the Valangian of Switzerland. The remaining two species, *Idmonea biserialis* and *Eschara holkari*, have their near allies in the Senonian of France.

Thus to consider this Bryozoan fauna in general, it does not seem unjustified to assign to them a horizon at about the Cenomanian, a conclusion which is not contradictory to the results arrived at from the study of the Echinoids and Rhynchonellids from this formation <sup>25</sup>.

As is already mentioned in the Introduction, the Bryozoa described here, are obtained in the main, both in number and kind, from the Upper Coralline Limestone, which is the uppermost member of the Bagh Beds.

<sup>25</sup> *Ibid.*, 7, 66-67, *ibid.*, 7, 312-13; *ibid.*, 9.

It is thus significant to note that the geological age assigned here to the present Bryozoan fauna is based on the study of the species mainly from the youngest member of the series

As to the alleged direct faunal affinities between the Bagh Beds of the Narbadha Valley and the Cretaceous Series of South India,<sup>26</sup> the present study of the Bryozoan fossils shows that no species are identical with, nor even allied to any of the forms described from South India.<sup>27</sup> On the contrary, these fossils are related to the Mediterranean biological province. The present study thus supplies clear evidence, in addition to that furnished by the Echinoids and the Rhynchonellids from these strata,<sup>28</sup> to show that the Narbada Valley and the Trichinopoly District belonged to two different basins of sedimentation with no direct connection between them and supported their own faunas.

#### *Acknowledgements*

I take this opportunity of expressing my great indebtedness to the late Prof K K Mathur for kindly placing at my disposal his collection of fossils which forms a part of the material for the present work. Very sincere thanks are due to Dr Raj Nath for his constant and keen interest in the present work and for his valuable criticism. I am very much thankful to the Director, the Geological Survey of India, for permission to work in their Survey Museum and Library. I take this opportunity of expressing my great indebtedness to the Dhar, Indore and Gwalior Durbars for the kind permission to collect fossils from their territories and for the facilities given during the field-work.

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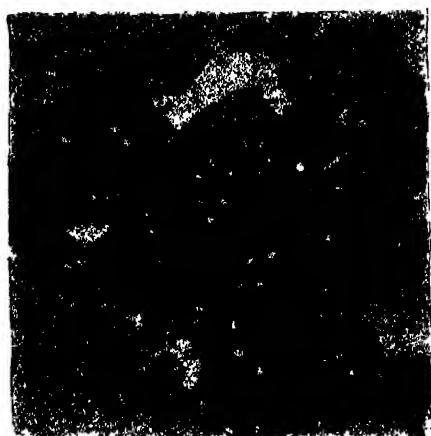
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EXPLANATION OF THE PLATES

PLATE III

- FIG. 1.—*Ceriopora micropora* sp. nov.; showing part of the zoarium  $\times 18$  (Holotype; B H U No B/5)
- FIG. 2. *Idmonea biserialis* sp. nov., showing part of the zoarium  $\times 18$  (Holotype; B H U. No. B/1)
- FIG. 3.—*Ceriopora coniformis* sp. nov., showing part of the zoarium  $\times 55$  (Holotype; B H U No. B/3)
- FIG. 4.—*Eschara regularis* sp. nov., showing part of the zoarium  $\times 18$  (Holotype, B H U. No. B/0).
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- FIG. 6.—*Ceriopora ellipsopora* sp. nov., showing part of the zoarium  $\times 18$  (Holotype, B H U No B/4)
- FIG. 7.—*Eschara chirakhanensis* sp. nov., showing part of the zoarium  $\times 18$  (Holotype; B H U No. B/8)
- FIG. 8.—*Membranipora pseudo normaniana* sp. nov., showing part of the zoarium  $\times 18$  (Holotype, B H U No B/7)
- FIG. 9.—*Idmonea biserialis* sp. nov., showing part of the zoarium.  $\times 18$  (Paratype, B H U No B/1-1)
- FIG. 10.—*Membranipora mathuri* sp. nov., showing part of the zoarium  $\times 18$  (Holotype, B H U. No. B/6)
- FIG. 11.—*Eschara holsti* sp. nov., showing part of the zoarium  $\times 18$  (Holotype, B H.U No. B/10)

PLATE IV

- FIG. 1.—*Ceriopora coniformis* sp. nov.; showing cross section of the zoarium  $\times 12$  (Holotype, B H.U No B/3)
- FIG. 2.—*Ceriopora dimorphopora* sp. nov.; showing cross section of a branch of the zoarium  $\times 12$  (Paratype, B H U No B/2-1)
- FIG. 3.—*Ceriopora dimorphopora* sp. nov.; showing part of the zoarium, natural size (Holotype, B H U No B/2)
- FIG. 4.—*Ceriopora ellipsopora* sp. nov.; showing part of the zoarium; natural size (Holotype, B.H U No B/4)
- FIG. 5.—*Ceriopora coniformis* sp. nov., showing part of the zoarium; natural size (Holotype, B.H U No B/3)



# STUDIES IN HELMINTHOLOGY\*

## Trematode Parasites of Birds

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## INTRODUCTION AND ACKNOWLEDGMENTS

BIRDS form one of the most important economic units of animals, some of them even constituting the delicacies of our table, but very little attention has so far been paid to the study of their Trematode parasites in India. In view of their economic importance and also in order to remove some existing confusion in the description and classification of these parasites, I determined, at the suggestion of Dr G S Thapar, to work out the morphology and the systematic position of Avian Trematodes from India. In spite of the fact that birds are migrants, results have not been disappointing and I have been able to collect materials and data that add to our knowledge of this group.

Part of the work has already been published and is referred to at its proper place in the thesis.

The work was carried out in the Zoology Department of the Lucknow University during the years 1934-36. I wish to record here my deep indebtedness to Dr G S Thapar for his kindly advice and criticism throughout the progress of my work. He further very kindly allowed me free access to his valuable personal library and placed part of his own collection of Avian Trematodes at my disposal for which I express my sincere thanks. Several other colleagues rendered valuable help in my work—Mr J Dayal in going through the typed manuscript, Dr (Miss) Dorothy Speer and Dr A C Chatterji in the translation of some German literature, Mr K S Iyer in going through some literature in French—and I take this opportunity to put on record my sense of gratitude for their help. I am also thankful to Mr G N Natu, our artist, for technical assistance in the preparation of illustrations. My thanks are also due to the authorities of the Zoological Survey of India for providing facilities to consult their Library. To Prof Birbal Sahni, F.R.S., I am indebted for the loan of a few journals from his private library, and last but not the least I am thankful to the authorities of the Lucknow University for facilities given to carry out these investigations.

## HISTORICAL REVIEW

The work on Avian Trematodes from India is hardly more than a decade old. The earliest record, to which I have been able to refer, is that of Bhalerao (1926) where he describes five species of Trematodes, viz., *Echinochasmus corvus*, *Stephanoprora reynoldi*, *Phaneropsolus insolens*, *Lyperosomum hakea* and *Platynosomum acuminatum* from the Burmese crow, *Corvus insolens*. Of these, *Platynosomum acuminatum* has previously been reported from the liver of a Kestrel from Scotland by Nicoll (1915).

Phadke and Gulati (1930) recorded a new genus *Multivitellaria* from the gall bladder of the common house crow, *Corvus splendens* and created a new subfamily *Multivitellarinæ* for its reception.

Moghe (1932) described two new species *Echinostomum govindum* and *Paramonostomum microstomum* from the rectal cæca and the small intestine respectively of the Indian Ruff, *Philomachus pugnax*.

Harshe (1932) described a new species *Catatropis orientalis* from the rectal cæca of the pintail duck, *Dafila acuta acuta*.

Gogate (1934) recorded four trematodes *Echinostoma revolutum*, *Paryphostomum testitrifolium*, *Petasiger minutissimus* and *Ornithobilharzia* sp from wild ducks in Rangoon.

Srivastava (1935) described a new species, *Ascocotyle intermedius*, from the intestine of the Indian Fishing Eagle, *Haliaeetus leucoryphus*, and further emended the diagnosis of the genus *Ascocotyle*. The same year (1935) he described another species, *Catatropis indicus* from the rectal cæca of an Indian fowl, *Gallus bankiva murghi*.

Bhalerao (1935) described two species, *Notocotylus baba* from the cæcum of the common kite, *Milvus migrans govinda*, and *Cyclocaelum sharadi* from the thoracic cavity of the western yellow-billed magpie, *Urocissa favirostris cucullata*.

Khan (1935) described eight new species of the genus *Cyclocaelum*, viz., *Cyclocaelum lobatum*, *Cyclocaelum nebularium*, *Cyclocaelum straightum*, *Cyclocaelum indicum*, *Cyclocaelum capellum*, *Cyclocaelum mehru*, *Cyclocaelum allahabadi* and *Cyclocaelum erythropsis* from three different genera of the Snipes.

Verma (1935) described *Echinochasmus bagula* from the small intestine of the Pond heron, *Ardeola grayi* and the Night heron, *Nycticorax nycticorax*, and also added *Echinochasmus ruficapensis* from the intestine of the Indian little grebe or diver, *Podiceps ruficollis*. In the same paper mention is made of a small variety of *Prosthogonimus* and two other representatives of the genus *Prosthogonimus*, but unfortunately no account of these forms is so far available. A chambered excretory bladder was described by Verma in the genus *Echinochasmus* and the diagnosis of the genus was emended, with a suggestion to split it up into two sub-genera.

Patwardhan (1935) recorded *Lyperosomum colorosum* from the gall bladder of a black-headed mynah, *Tenenuchus pagodarum*; *Proalaria alcedenes* from the intestine of the king-fisher, *Alcedo atthis*, and *Neodiplostomum tytense* from the intestine of a Barn owl, *Tyto alba stertens*.

Thapar and Lal (1935) added a new genus *Psilorchis* under the family Psilostomidae from the intestine of the king-fisher and considered the evolution of several structures in the family Psilostomidae.

Later, Lal (1935) described a new species *Notocotylus indicus* from the intestinal cæca of the wigeon, *Mareca penelope*.

Again, Lal (1935) reviewed the genus *Notocotylus* and discussed the importance of the position of the genital opening. On the basis of this character he created two new genera, *Hindia* and *Naviformia*.

Lal (1936) described two new species of the genus *Paramonostomum*, viz., *Paramonostomum querquedulae* from the intestinal cæca of the garganey, *Querquedula circum*, and *Paramonostomum casarcum* from the intestinal cæca of the Brahminy duck, *Casarca rutila*. The value of the position of the genital pore as of generic importance in the classification of the members of the subfamily Notocotylinae was further confirmed, and a new genus *Neoparamonostomum* was created.

Verma (1936) recorded thirty-three new forms of trematodes from Indian birds but gave no diagrams and added very meagre and incomplete descriptions. It is, therefore, not easy to diagnose and include these forms with their present confused account at this stage, particularly because the author himself, as appears from his paper, is in doubt regarding the description of many of his forms. The same year (1936) he also described *Cyathocotyle calvus* from the intestine of the King Vulture, *Torgos calvus*.

Lal (1936) described a new species *Parorchis snipes* from the cloaca of the common summer snipe, *Totanus hypoleucus*. The discovery of a species of *parorchis* from India in the snipe is interesting in so far as this genus has only been recorded from gulls and restricted only to St Andrews, Northumberland coast, Millport and America. In the course of a discussion on the systematic position of the genus a new subfamily Parorchininae was created for its reception, and a suggestion was put forward regarding the polyphyletic origin of the family Echinostomatidae.

Lal (1936) while describing a new genus *Typhlophilus shovellus* from the intestine of a shoveller duck, *Spatula clypeata*, demonstrated the presence of a well-developed muscular ventral sucker in the family Cyclocælidæ and also discussed the advisability of retaining the subfamilies Cyclocælinæ and Typhloælinæ. The significance of a ventral sucker as a basis for generic divisions was also pointed out.

Lal (1936) recorded a new species *Levinsenella indica* and suggested the probable identity of several existing species of the genus with the genus *Maritrema* owing to the presence of a cirrus sac.

It would, thus, appear that so far† only scattered contributions have been made in India on the Avian trematodes and no comprehensive and collective work has been attempted. I have, therefore, endeavoured to present here the results of my investigations, together with summaries of descriptions of other forms given by earlier workers. The latter is indicated by *small type* to differentiate it from new and original work.

#### COLLECTION OF MATERIAL

A large number of birds were subjected to post-mortem examinations in normal salt solution during the years 1934-36, and the Trematodes recovered from them are enumerated in the following table:

Locality of the host	Name of host	No. examined	No. infected	Location of parasite	Name of the trematode
Malhaar	<i>Casarca rutila</i> (Brahminy duck)	6	2	Intestinal caeca	<i>Paramanostomum casar-</i> <i>cum Lal, 1936</i>
Lucknow	<i>Totanus hypoleucus</i> (Summer snipe)	4	1	Cloaca	<i>Parorchis snipes Lal,</i> <i>1936</i>
..	<i>Gallinago gallinula</i> (Jack snipe)	3	1	Bursa Fabricii	<i>Levinsenella indica Lal,</i> <i>1936</i>
..	<i>Spatula clypeata</i> (Shoveller duck)	4	1	Intestine	<i>Typhlophilus shovellius</i> <i>Lal, 1936</i>
..	<i>Mareca penelope</i> (The Wigeon)	7	4	Intestinal caeca	<i>Notocotylus indicus Lal,</i> <i>1935 and Hindia luck-</i> <i>nowensis Lal, 1935</i>
..	<i>Totanus fuscus</i> (Spotted red shank)	9	3	Intestine	<i>Stephanopra fuscana</i> sp
..	<i>Dicrurus macrocercus</i> (King crow)	4	0		..
Lucknow and Sitapur	<i>Upupa epops</i> (The Hooper)	9	0		..
Lucknow	<i>Ardeota grayi</i> (Paddy bird)	8	6	Intestine	<i>Echinochaetus megalost-</i> <i>mus n. sp</i>

† Since submission of the thesis Mehra (1937) described *Lepoderma bulbulis*, *Lepoderma casarci*, *Lepoderma ferruginum*. Vidyarthi (1937) described *Apharyngostrix ardeolina*, *A. indiana*, *Strigea orientalis* and *Strigea nephronis*. Chatterji (1938) mentions *Prosthoronimus* sp. and *Catatropis verrucosa*. Pande (1938) describes *Crassiphilus stunkardii*. The characters of these species are not summarized here.

Locality of the host	Name of host	No. examined	No. infected	Location of parasite	Name of the trematode
Lucknow	<i>Ardea cinerea recitros</i> <i>tree</i> (Common grey heron)	6	1	Intestine	<i>Pharyngostomum bagulum</i> n sp
"	<i>Athene Brama</i> (Spotted owllet)	4	2	Small intestine	<i>Neodiplostomum dilacae</i> <i>cum</i> n sp
"	<i>Passer domesticus</i> (House sparrow)	11	0		
Barabanki and Sitapur	<i>Kittacincla malabarica</i> (Shama)	9	0		
Lucknow	<i>Milvus migrans</i> (Common kite)	7	3	Liver	<i>Opisthorchis cheela</i> n sp
"	<i>Sarcogyps calucus</i> (King vulture)	9	4	"	<i>Opisthorchis giddingsi</i> n sp
"				Intestine	<i>Neocalaris thaparia</i> n g., n sp
"	<i>Acridotheres tristis</i> (The mynah)	2	1	Bursa fabricii	<i>Prosthognathus cuneatus</i>
Amausi	<i>Querquedula circia</i> (The garganey)	9	5	Intestinal caeca	<i>Paramonostomum quer</i> <i>quedulum</i> Lal, 1936
				Small intestine	<i>Echinostoma chasma</i> n sp
Lucknow	<i>Halcyon smyrnensis</i> (King fisher)	6	1	Intestine	<i>Palorchus indicus</i> Thapar and Lal, 1935
"	<i>Pittaacula krameri</i> (Green parakeet)	10	0		
"	<i>Coracias benghalensis</i> (The blue jay)	6	1	Intestine	<i>Neodiplostomum</i> sp
"	<i>Corvus splendens</i> (Common house crow)	10	2	"	<i>Echinocystis renovarum</i> n sp
Lucknow and Sitapur	<i>Cinnyris seylonicus</i> (Sun bird)	8	0		
Ajgaon and Chinchut	<i>Nettion crecca</i> (Common Teal)	5	2	Intestine	<i>Palorchus Ajgaonis</i> Lal, 1938
			1	Main blood vessels Kidney, Lung, Liver, etc	<i>Chinchuta indica</i> Lal, 1937
Kukrail, Lucknow	<i>Sterna aurantia</i> (Common river tern)	8	0		.
Lucknow	<i>Bubulcus ibis coro-</i> <i>mandus</i> (Cattle egret)	5	1	Renal vein	<i>Gigantobilharzia egretta</i> Lal, 1937

### TECHNIQUE

Most of the Trematode material collected was fixed under slight pressure of the coverglass in 90% alcohol. Some forms were fixed in Bouin's Fluid and Chrom-osmic for section-cutting. In certain cases a special method of narcotising and killing the worms in 5% alcohol and gradual transfer to 30% alcohol was found very useful. The worms, thus treated, were fixed in a well-stretched condition without pressure and displacement of organs or injury to parts. This was specially helpful in examining the ventral glands of the family Notocotylidæ. The material was preserved in all cases in 70% alcohol or sometimes in 70% alcohol-glycerine. The specimens for whole mounts were stained with Ehrlich's acid hæmatoxylin in a dilution of 1 : 20 of distilled water and differentiated in tap-water overnight. This procedure gave a uniformly brilliant stain. Paracarmine stain was also used. Although it stained the structures rather deep, it gave good results in differentiating some of the deep-seated structures. Clearing was done in Clove oil or Xylol. In certain cases sections, both transverse and longitudinal, were cut, and for this double embedding Celloidin-Paraffin method was used. The sections were stained with hæmatoxylin (Delafield's) and Eosin.

A special glycerine-alcohol method of clearing was found useful in certain cases, specially in the Echinostomidæ. The unstained material was kept in 70% alcohol-glycerine in proportion of 3 : 1 and left for about half an hour. Later it was transferred to 90% alcohol-glycerine in proportion of 4 : 1 and left overnight. The alcohol gradually evaporates leaving specimens in pure glycerine which also thoroughly penetrates into the specimens. The spines, reproductive organs, genital pore, etc., were easily seen by this method.

### CLASSIFICATION

#### *(a) Characters of Systematic Importance*

The author has already published a separate paper on this aspect of the subject and has fully discussed the value of different characters in the classification of Avian Trematodes (*vide* these *Proceedings*, 1937, 5, No 2, Sec B, 33-44).

The systematic account of the various families given in the following pages is on the lines of the views expressed in the above published paper.

#### *(b) Systematic Description of the Families*

##### *Family Notocotylidæ Lühe, 1909*

The family Notocotylidæ was formed by Lühe (1909) to contain originally only three genera *Notocotylus*, *Catatropis* and *Paramonostomum*.

Later on several workers added to this list with the result that the family was split up into three subfamilies, Notocotylinæ, Nudacotylinæ and Ogmo-gasterinæ.

The writer in the course of his investigations on the family observed certain peculiar features, described later, which necessitates the modification of the existing diagnosis of the family. The emended diagnosis is as follows:—

*Diagnosis of the family Notocotylidæ Iuhe, 1909, emended*—

Trematodes with flat body, without a head-collar. Skin smooth or thickly covered with fine spines in the anterior part of the body and whole of the ventral surface. *Ventral papillæ very rarely present*. The ventral surface provided in most cases with regular rows of unicellular glands. Oral sucker simple. Ventral sucker absent. Pharynx not present. Oesophagus short. Intestinal cæca simple and end blindly. Excretory pore slightly dorsal. Excretory bladder with a short unpaired median stem and a pair of long limbs which branch and anastomose dorsal to the oesophagus. Testes symmetrical at the posterior end, lateral to the intestinal cæca. Cirrus sac very long. *Vesicula seminalis lying external or partly internal and partly external*. Ovary lies between the testes. Shell-gland in front of ovary. Receptaculum seminis absent. Laurer's canal present. Uterus runs in fairly regular transverse loops between the intestinal cæca and in front of the ovary. Vitellaria well-developed and lie in front of the testes, mostly extra-cæcal. *Genital pore pre-equatorial and median, behind the intestinal bifurcation or in front of it, sometimes far forward at the side of the oral sucker or post-equatorial and lateral*. Eggs with long thread-like filaments at both ends. Parasitic in aquatic Birds and Mammals.

Of the three subfamilies, Notocotylinæ, Nudacotylinæ and Ogmo-gasterinæ, only Notocotylinæ is recorded from avian hosts in India.

*Diagnosis of the subfamily Notocotylinæ Kossack, 1911, emended*—

Notocotylidæ, generally with 3–5 rows of ventral glands on the ventral surface, sometimes absent. *Vesicula seminalis lying external or partly internal and partly external*. Genital pore almost median, pre-equatorial, behind or in front of the intestinal fork. Vitellaria well-developed in the posterior half of the body and lateral to intestinal cæca. Testes at the extreme end of the body, symmetrical. Ovary intertesticular, separated from testes by intestinal crura. Uterine coils intercæcal.

Type genus—*Notocotylus* Sens Str.

The author has already made elaborate studies on the various genera of the subfamily Notocotylinae and as a result of his investigations the following genera have been recognized under the subfamily :

Genus *Notocotylus* Sens Str (Lal, 1935)

- .. *Hindia* Lal, 1935
- .. *Naviformia* Lal, 1935
- .. *Paramonostomum* Sens Str (Lal, 1936)
- .. *Neoparamonostomum* Lal, 1936
- .. *Catatropis* Odhner, 1905

Genus *Notocotylus* Sens Str (Lal, 1935)

Monostomes with two to five rows of protrusible ventral glands, pharynx absent, testes extra-cæcal and posterior, ovary in between testes, shell-glands pre-ovarial, uterine loops confined to the inter-cæcal region behind the cirrus sac, receptaculum seminis absent, part of the vesicula seminalis enclosed within cirrus sac, cirrus sac never extending beyond half of body length, vagina about  $\frac{1}{2}$  to as long as cirrus sac, genital pore situated behind the intestinal bifurcation, vitelline glands extend upto the middle of the body, eggs 018- 022 mm long with filaments at either end

Type species—*Notocotylus attenuatus*

*Notocotylus indicus* Lal, 1935

Monostome measuring 2 18 mm  $\times$  63 mm Three rows of protrusible ventral glands, 17, 16, 17 Oral sucker subterminal 12 mm  $\times$  13 mm Oesophagus 075 mm long Intestinal cæca terminate at a distance of 2 mm on the right and 19 mm on the left side from the posterior end Right testis 36 mm long, left testis 38 mm long Cirrus sac .58 mm long Ovary 18 mm  $\times$  16 mm Eggs small and numerous with thin shell and a filament at each end, measuring 018 mm  $\times$  011 mm without filaments

Host—*Mareca penelope* (Intestinal cæca)

Locality—Lucknow

Genus *Hindia* Lal, 1935

Monostomes with three rows of protrusible ventral glands, pharynx absent, testes extra-cæcal and posterior, ovary in between testes, shell-glands pre-ovarial, uterine loops lie in the inter-cæcal region behind the

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‡ Vide Proc. Ind. Acad. Sci., 1935, 2, No 5, 419-23 and 457-66. Also 1936, 3, No. 1, 25-34

cirrus sac, receptaculum seminis absent, part of the vesicula seminalis enclosed within the cirrus sac, cirrus sac extending about  $\frac{1}{2}$  to  $\frac{1}{3}$  body length; vagina never more than  $\frac{1}{2}$  of the cirrus sac, genital pore at the intestinal fork, vitelline glands extend  $\frac{1}{2}$  to  $\frac{1}{3}$  of the body length from the posterior end, eggs 014--0209 mm long, with filaments at either end

Type species—*Hindia gibbus*

*Hindia lucknowensis* Lal, 1935

Monostome measuring 2 63 mm  $\times$  74 mm Ventral glands 16, 15, 16  
 Oral sucker subterminal 15 mm in diameter Oesophagus 13 mm long  
 Intestinal cæca terminate at a distance of 2 mm on the right and 15 mm  
 on the left side from the posterior end Right testis 35 mm  $\times$  175 mm  
 Left testis 375 mm  $\times$  2 mm Cirrus sac 825 mm long Cirrus about  
 3 mm long, armed with several rows of spine Ovary 175 mm  $\times$  15 mm  
 Eggs with thin shell and a filament at each end, measuring 02 mm  $\times$   
 01 mm excluding filaments

Host—*Mareca penelope* (Intestinal cæca)

Locality—Lucknow

*Hindia babai* (Bhalerao, 1935) Lal, 1935

(Syn *Notocotylus babai* Bhalerao, 1935)

Body small, elongate, ellipticle, measuring 3 83 mm in length and 93 in maximum breadth a little behind anterior end Cuticle covered with minute spines Three rows of uniform and eversible ventral glands present, lateral ones with 17 glands each, and middle one with 15 glands Oral sucker is sub-terminal and measures 2mm  $\times$  16 mm Oesophagus measures 12 mm in length The intestinal cæca end at a distance of .265 mm from posterior end Testes, elongate, deeply lobed, symmetrical, extracæcal and measure 535—545 mm  $\times$  24—2mm Cirrus sac, elongated, club shaped and measures 1 09 mm. Genital pore median, ventral to intestinal bifurcation. Vesicula seminalis present inside the cirrus sac Para prostatica wide and elongated, measures .435 mm. narrow muscular, eversible cirrus measures 575 mm Ovary deeply lobed, median, in between two testes It measures 3  $\times$  .31 mm Shell-gland, pre-ovarian and measures 235 mm  $\times$  165 mm Oviduct enlarges into uterus which passes anteriorly in 18 transverse loops which are mostly intercæcal Vagina measures .56 mm Laurer's canal present Receptaculum seminis absent Vitellaria follicular, extra-cæcal, a portion intercæcal They extend between anterior border of testes to anterior 3/5 of the body Yolk reservoir dorsal to shell-gland. Eggs measure .014—.017 mm  $\times$  .008—.011 mm with long filaments at either pole. A short excretory bladder Excretory pore dorsal and median near the posterior end

Host—*Milvus migrans govinda* (Cæcum)

Locality—Rangoon

Remarks—The form is transferred to the genus *Hindia* because of the position of its genital pore and other characters

Genus *Naviformia* Lal, 1935

Monostomes with three rows of protrusible ventral glands, pharynx absent, testes extra-cæcal and posterior, ovary in between the testes; shell-glands pre-ovarial, uterine coils lie in the inter-cæcal region behind the cirrus sac, receptaculum seminis absent, part of the vesicula seminalis is enclosed within the cirrus sac, cirrus sac extending about  $\frac{1}{2}$  of the body length, vagina  $\frac{1}{2}$  of the cirrus sac, genital pore in front of the intestinal fork, vitelline glands behind mid-body, eggs 0178 mm  $\times$  .0208 mm long, with filaments at either end

Type species—*Naviformia naviformes*

No species recorded from birds from India

Genus *Paramonostomum* Sens Str (Lal, 1936)

Monostomes without ventral glands and a pharynx, intestinal cæca run almost upto the posterior end of the animal, testes may or may not be lobed, extra-cæcal in the posterior part of the body, part of the vesicula seminalis enclosed within the cirrus sac, ovary in between the testes, shell-glands pre-ovarial, uterine loops mostly confined to the inter-cæcal region behind the cirrus sac, receptaculum seminis absent, genital pore always opens in front of the intestinal fork and behind the oral sucker, vitelline glands never end behind the mid-body from the posterior end, eggs with filaments at either end

*Paramonostomum querquedula* Lal, 1936

Monostome measures 3 398 mm  $\times$  1 11 mm Oral sucker 17 mm  $\times$  .12 mm Oesophagus 165 mm long. Right testis 66 mm  $\times$  24 mm Left testis .74 mm  $\times$  235 mm Cirrus sac 93 mm long Ovary 265 mm,  $\times$  22 mm Eggs with thin shell and a filament at each end, measuring .02 mm  $\times$  .009 mm without filaments

Host—*Querquedula circia* (Intestinal cæca).

Locality—Amausi

*Paramonostomum casarcum* Lal, 1936

Monostome measures 3 8 mm  $\times$  95 mm Oral sucker .14 mm  $\times$  .1 mm Oesophagus 14 mm long. Right testis 8 mm  $\times$  15 mm Left testis 76 mm  $\times$  .175 mm Cirrus sac 91 mm long Ovary .38 mm  $\times$  22 mm Eggs thin-shelled and provided with a filament at each pole; measuring 015 mm  $\times$  .01 mm without filaments

Host—*Casarca rutila* (Intestinal cæca)

Locality.—Malhaur, Lucknow.

**Genus *Neoparamonostomum* Lal, 1936**

*Monostomes without ventral glands and pharynx; intestinal cæca run almost upto the posterior end of the animal, testes extra-cæcal and posterior and generally lobed, part of the vesicula seminalis enclosed within the cirrus sac, ovary in between the testes, shell glands pre-ovarial, uterine loops mostly confined behind the cirrus sac, receptaculum seminis absent; receptaculum seminis uterinum may be present, genital pore always opens behind intestinal fork, vitelline glands end behind mid-body from the posterior end, eggs with filaments at either end*

Type species—*Neoparamonostomum ionorne*

(Syn *Paramonostomum ionorne* Travassos)

*Neoparamonostomum microstomum* (Moghe 1932) Lal, 1935

(Syn *Paramonostomum microstomum* Moghe, 1932)

Body elongated, 1.348 mm—1.624 mm long Maximum width .375 mm—.409 mm. anterior to testes Oral sucker, small, terminal, .068 mm in diameter Ventral sucker absent Very short oesophagus, pharynx and prepharynx absent Intestinal cæca extend up to .05 mm from posterior end Testes, extra-cæcal at the posterior end of animal, elongated, and lobed, 13—15 mm long Cirrus sac in anterior half of body, between the intestinal cæca, .418 mm long It contains vesicula seminalis straight and narrow, and opens at genital pore, immediately below the intestinal bifurcation Ovary lies in the median line between the testes, intercæcal, shell-gland posterior to ovary Uterus with 13–15 loops on either side Vagina as long as cirrus sac Uterus extends along more than  $\frac{1}{2}$  of the body Vitellaria extend from anterior end of testes to about middle of the uterus region Eggs provided with long polar filaments and measure .051 mm long.

*Host*—*Philomachus pugnax* (Small intestine).

*Locality*—Nagpur

*Remarks*—It is rather peculiar that the shell-gland has been described by Moghe posterior to the ovary, a condition which is unique in the family Notocotylidae This apparently appears to be a case of misrepresentation of structures as has been pointed out by some other authors also But in case the post-ovarian position of shell-gland is confirmed in other specimens, it would not only affect our concept of the family Notocotylidae but would also place it still nearer the family Pronocephalidae

**Genus *Catatropis* Odhner, 1905**

*Monostomes with three rows of weakly developed non-protrusible ventral glands, the middle row of ventral glands may be placed on a median keel or a ridge; pharynx absent, testes extra-cæcal and posterior, ovary inter-testicular; shell-gland pre-ovarial, vesicula seminalis is divisible into an*

external and an internal portion, receptaculum seminis absent, *vagina* is very much developed, about as long as cirrus sac, genital pore situated behind the intestinal fork, eggs with filaments at either pole

Type species—*Catatropis verrucosa*

*Catatropis orientalis* Harshe, 1932

**Remarks**—Harshe while describing this new species does not mention anything about the nature of the ventral glands present, whether they are protrusible or non-protrusible. The question of protrusibility or non-protrusibility is a vital one, as it is the most important difference by which *Catatropis* is distinguished from *Notocotylus*, *Hindia* and *Naviformia*. This species, therefore, should in the opinion of the writer, be kept as a *species inquirendum* till more light is thrown by a reinvestigation of the form and hence the characters of *Catatropis orientalis*, sp inq are not summarised here.

*Catatropis indicus* Srivastava, 1935

Worms light brown in colour, 4.6 mm long and 1.2 mm broad. Dorsal surface convex, ventral surface concave with 3 longitudinal rows of non-protrusible unicellular glands—glands in median row contiguous, those in lateral rows distinct and 10–12 in number in each row. Excretory system similar to that seen in *Catatropis*. Oral sucker 14–2 mm in diameter, oesophagus 2–2.6 mm long, pharynx absent. Testes deeply lobed, 75–90 mm × 2–3 mm, extracecal, vesicula seminalis enormous, outside the cirrus sac. Cirrus sac flask-shaped, 87–1.2 mm long and 17–2 mm. broad containing cone-shaped pars prostatica, 35 mm × 09 mm surrounded by prostate cells. Genital pore close behind oral sucker. Ovary lobed, 26–35 mm. size, intercecal, in level with testes and posterior to shell-gland. Laurer's canal present. Receptaculum seminis absent. Vitellaria, irregular follicles. Receptaculum seminis uterinum present. Uterus in transverse coils. Metraterm muscular as long as cirrus sac. Eggs thin shelled, with long polar filaments. They measure 0.17–0.2 mm × 0.08–0.1 mm without filaments.

**Host**—*Gallus bankiva murghi* (Rectal cæca).

**Remarks**—This form is remarkable in having the genital pore far forwards at the posterior margin of the oral sucker. This position of the genital pore appears to be unique for the genus. The vesicula seminalis also is wholly external in *Catatropis indicus*. The importance of this character was emphasized by Chatterji (1933) who created a new genus *Ganada* in the subfamily Lepodermatinae on the presence of an external vesicula seminalis, besides the usual internal vesicula seminalis. Owing to the unique position of the genital pore, the absence of a median ridge or keel for bearing ventral glands and lastly in the absence of an internal vesicula seminalis the writer feels inclined to remove this species from the

genus *Catatropis* Probably a re-study of more material of this form will necessitate the creation of a new genus for this species

*Remarks on the family Notocotylidae*—In the preceding pages and also earlier in the pages of these *Proceedings*\* the writer has given an account of the subfamily Notocotylinæ. The sub-families Nudacotylinæ and Ogmogasterinæ possess such distinctive characters when compared with Notocotylinæ that there could be no doubt for their retention as distinct subfamilies. Yamaguti (1933) described a new genus *Cymbiforma* from the intestine of a mammal, *Sika nippone* and created the subfamily Cymbiforminæ for its reception. The genus shows affinities with the members of the subfamily Nudacotylinæ but differs in the relative position of the cirrus sac and uterine coils. Yamaguti also mentions, that Barker (1915), in describing the subfamily Nudacotylinæ, covered variations in these characters as well. It would, thus, appear that the difference in the relative position of uterine coils and cirrus sac should not form a sufficient basis for the erection of a new subfamily Cymbiforminæ. The question of a mammalian host lodging this form may rise a little doubt but as already discussed earlier in the Host-parasite relationship (*vide* these *Proceedings*, 1937, 5, No 2, Sec B, 33-44) this point may be negligible. The sub-family Cymbiforminæ may, therefore, be dropped and be regarded as a synonym of the subfamily Nudacotylinæ, and the genus *Cymbiforma* thus comes under the subfamily Nudacotylinæ.

#### *Family Cyclocælidae Kossack, 1911*

Stosich (1902) created a subfamily Cyclocælinæ for the reception of four genera, *Cyclocælum*, *Hæmatotrephus*, *Ophthalmophagus* and *Typhlocælum*. Kossack (1911) raised it to the status of a family, Cyclocælidæ and added to it two genera, *Hyptiasmus* and *Spaniometra*. He also included the genus *Bothriogaster* under this family. Harrah (1922), while revising the monostomes of North America, divided the family into three subfamilies —

- (1) Cyclocælinæ with *Cyclocælum*, *Hæmatotrephus* and *Hyptiasmus*
- (2) Typhlocælinæ with *Typhlocælum* and *Tracheophilus*
- (3) Ophthalmophaginiæ with *Ophthalmophagus*, *Bothriogaster* and *Spaniometra*

Witenberg (1926) fused the subfamilies Ophthalmophaginiæ and Cycloælinæ, leaving only two subfamilies, Cycloælinæ and Typhlocælinæ. The

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\* *Vide* 1935, 2, No. 5; and 1936, 3, No. 1.

main point on which Witenberg maintained only two subfamilies is the absence or presence of caecal diverticula.

*Family diagnosis* — Trematodes, large to medium size with strong muscular flat body, small ventral sucker sometimes present Mouth terminal or subterminal, oral sucker rudimentary, mostly absent. Pharynx non-muscular Intestinal cæca join each other at the posterior end They are either simple or provided with lateral diverticula on their inner margin Excretory pore dorsal and short, situated at the posterior end Genital pore median, not very much behind the mouth opening. Copulatory organ present but feebly developed Seminal vesicle lies inside the cirrus sac. Vitellaria, lateral, between body-wall and intestine, sometimes run continuously along the intestine and meet at the posterior end. Gonads intercæcal Testes two, simple or pressed, and lie near each other Ovary, always entire and spherical Laurer's canal and receptaculum seminis exceptionally present Uterus very strongly developed with regular peculiarly pointed loops and extends from the posterior end up to the intestinal bifurcation Eggs numerous, without polar filaments and producing miracidia with two eyespots while still inside the uterus Generally parasitic in the body cavity, air-sacs and nasal opening of aquatic birds. Exceptionally present in the intestinal canal

Type genus—*Cyclocaelum*

The family is divided into two subfamilies —

- (1) Cyclocoelinae—without lateral intestinal diverticula
- (2) Typhlocoelinae— with lateral intestinal diverticula

The Avian Trematodes reported from India under the subfamily Cyclocoelinae belong to the following genera.—

1 *Hematotrephus*.

2 *Cyclocaelum*.

Key for the identification of the Indian genera of the subfamily Cyclocoelinae .

Ovary in front of both the testes which are not separated by uterine coils—*Hematotrephus*.

Ovary in between two testes which are always separated by uterine coils—*Cyclocaelum*.

Genus *Hæmatotrephus* Stossich, 1902

Only one species has been reported from avian host in India

*Hæmatotrephus nebularium* (Khan, 1935)

(Syn *Cyclocælum nebularium* Khan, 1935)

Trematodes with medium size, 10–13 mm long and 2·3–5 mm broad. Pharynx well-developed. Oesophagus S-shaped or straight. Intestinal area devoid of lateral diverticula and meet posteriorly in an arc 285 mm in front of the posterior end. Excretory bladder between the intestinal arc and posterior end of the body, with dorsally placed excretory pore. The two round testes lying obliquely behind the ovary measure 0·7–1 mm in diameter and are not separated by uterine coils. Cirrus sac tubular, dilated posteriorly, extending from the genital pore to the anterior end of the intestinal bifurcation. Ovary rounded, smaller than testes, and measures 31–41 mm. in diameter. Laurer's canal absent. Uterus in transverse loops with large thick-shelled eggs. Vitellaria, confined to the extreme edges of the body. A small yolk reservoir is present. Eggs, without operculum showing miracidia with characteristic double eyepot, and measuring 12 mm. × 0·87 mm. in size.

Host — *Glotis nebularia* (Abdominal air-sacs)

Locality.—Allahabad

Remarks — Khan who included this species under the genus *Cyclocælum* has described a small structure lying inside the ovary which he calls a receptaculum seminis. This position of receptaculum seminis is rather peculiar. It is further interesting to note that Khan does not find any sperms in it and he mentions that Morishita (1924) had termed a similar structure as ootype. The present writer considers that the structure is possibly not of the nature of receptaculum seminis which evidently is absent in this form. Owing to the pretesticular position of the ovary, the species is removed to the genus *Hæmatotrephus*.

Genus *Cyclocælum* Brandes, 1892

Nine species of this genus have so far been recorded from Avian hosts in India. Out of these one *Cyclocælum nebularium* has just been allocated to the genus *Hæmatotrephus*. Of the remaining eight, seven have been described to possess a receptaculum seminis which is absent in the genus *Cyclocælum*.

*Cyclocælum erythrops* Khan, 1935

Length 7·5–17 mm. Maximum breadth 1·7–2·3 mm. Oral sucker feeble, ·15 mm. × ·1 mm. Pharynx ·15–2·5 mm. in diameter. Oesophagus more or less straight. Intestinal arc ·15 mm. in front of the posterior end. Excretory bladder ·12–·15 mm. by ·19–·34 mm. in size. Excretory pore median, dorsally situated at hinder end. Gonads in posterior fifth of the body. Testes spherical, anterior testis separated by four or five uterine coils from posterior testis. Vesicula seminalis straight.

and inside the cirrus sac. Genital pore, ventral, just behind the pharynx. Cirrus sac club-shaped, reaching middle of intestinal bifurcation. Ovary very small  $\cdot 19 \text{--} 29$  mm. in diameter, shell-gland mass spherical, uterus runs forward in closely situated coils, metraterm short. Vitellaria laterally pressed against body-wall. Thin-shelled ova.

*Host* — *Tringa erythropus*

*Locality* — Allahabad

*Remarks* — This species definitely conforms to the characters of the genus *Cyclocælum*. It does not possess a receptaculum seminis and differs in this important feature from the other species which have been described to possess a receptaculum seminis.

### *Cyclocælum sharadi* Bhalerao, 1935

Trematodes with body tapering towards both ends, medium size, measuring 10.5–11 mm in length and 4.4–5 mm in maximum breadth. Oral sucker, muscular, measuring 4.1 mm  $\times$  3.2 mm. Prepharynx short. Pharynx well developed, muscular, and measures 1.25 mm  $\times$  .98 mm. Oesophagus short. Excretory bladder, simple, flat sac, excretory pore opens dorsally by a short duct. Nerve ganglia on either side of the pharynx, a dorsal nerve-band joins them. Genital glands in posterior fourth of the body. Testes separated by uterine coils. Posterior testis in contact with intestinal arc and measures 2.15 mm  $\times$  1.32 mm. Anterior testis measures 2.07 mm,  $\times$  1.7 mm. and is in contact with left intestinal cæcum. Cirrus sac small with cirrus in the form of horizontal S. Vesicula seminalis large, fills up the cirrus sac. Pars prostatica non-cellular, prostate glands present. Male opening in the genital atrium. Genital atrium large and situated posterior to the pharynx, genital pore slightly behind pharynx. Ovary, between two testes, oval, measures .5 mm  $\times$  4.3 mm. Shell-gland, larger than ovary on the left of the latter. Receptaculum seminis, oval, on the left of ovary between it and testis. It measures 3.0 mm  $\times$  .275 mm. Vitellaria between cæca and margin of body, extending upto hinder border of pharynx. Laurer's canal absent. Uterine coils in posterior 3rd, intercæcal, metraterm strongly muscular, surrounded with gland-cells. Long and elliptical eggs 12.3–14 mm  $\times$  0.6–0.81 mm.

*Host* — *Urocissa favirostris cucullata* (Thoracic cavity)

*Locality* — Muktesar

### *Cyclocælum allahabadi* Khan, 1935

Size 17 mm  $\times$  2.5–3 mm. Oral sucker flat. Pharynx 2.8 mm in diameter. Oesophagus S-shaped. Testes separated from each other by uterine coils. Genital pore at posterior end of pharynx. Cirrus sac club-shaped, extending upto middle of intestinal bifurcation. Ovary, 3.05 mm  $\times$  2.25 mm in size. Receptaculum seminis inside the ovary and well developed. Receptaculum seminis uterum absent. Shell-gland posterior and left to ovary. Uterus fills up the body between posterior testis and intestinal bifurcation. Vitellaria, extending over cæca at places and reaching uterine coils. Ova thin-shelled and operculate, 1.19 mm  $\times$  0.8 mm.

*Host* — *Tringa erythropus* (Thoracic air-sac)

*Locality* — Allahabad

*Cyclocaelum capellum Khan, 1935*

Body 17-25 mm  $\times$  3.5-4.0 mm Oral sucker rudimentary Pharynx .275 mm in diameter. Oesophagus S-shaped or straight Excretory pore dorsal and terminal. Testes separated from each other by uterine coils, anterior testis to the right side and .8 mm  $\times$  .6- .8 mm in size, posterior, median, much-lobed, 1.1 mm  $\times$  7-.88 mm. in size Genital pore at posterior margin of pharynx Cirrus sac flask-shaped and hardly reaching intestinal bifurcation Ovary to the left side .37-.55 mm  $\times$  .37-.5 mm Shell-gland behind ovary Receptaculum seminis pear-shaped on the inner side of the ovary Receptaculum seminis uterini filled with sperms Uterus thrown into double loops, never overlapping caeca Vitellaria, irregular in extension on two sides, yolk reservoir present, 15 mm long Ova with fully developed miracidia, .13 mm  $\times$  .068 mm

*Host* — *Capella gallinago* (Cervical air-sacs)

*Locality* — Allahabad

*Cyclocaelum straightum Khan, 1935*

Body long, 25 mm  $\times$  4.3 mm in size, oral sucker feebly developed, ventral sucker absent Pharynx 344 mm  $\times$  425 mm Oesophagus S-shaped or straight Excretory pore dorsal and terminal Testes separated from each other by uterine coils, anterior to the right side and 1.05 mm  $\times$  .68 mm, posterior mesial, 1.25 mm  $\times$  .99 mm Cirrus sac nearly flask-shaped reaching to 15 mm in front of intestinal bifurcation Pars prostatica, prostate glands and cirrus not observed Ovary, median, 45 mm  $\times$  41 mm in size Shell-gland to left of ovary, receptaculum seminis immediately behind ovary, Lauder's canal absent Receptaculum seminis uterini large, filled with sperms Uterus filling up the space upto intestinal bifurcation Vitellaria from middle of intestinal bifurcation to excretory bladder A small yolk reservoir present Ova, thick-shelled, non-operculate, with fully developed miracidia, 138 mm  $\times$  .068 mm

*Host* — *Glottis nebularia* (Abdominal air-sac)

*Locality* — Phulpur, Allahabad

*Cyclocaelum indicum Khan, 1935*

Length 20-27 mm Breadth 4-4.5 mm Rudimentary oral sucker Pharynx .28 mm. in diameter Oesophagus straight Excretory pore dorsal at hinder end. Testes separated from each other by uterine coils, anterior, to the left and .85 mm. in diameter, posterior, in the intestinal arc 85-93 mm. in diameter Cirrus sac club-shaped Genital pore behind pharynx, median Ovary .5- .6 mm in diameter, shell-gland near right wall of ovary, receptaculum seminis elongated inside the ovary Receptaculum seminis uterini present Uterus with widely separated loops, extending over caeca and reaching body wall Vitellaria irregular in extension on the two sides Ova, thin-shelled with fully developed miracidia, measure 0.12 mm  $\times$  .068 mm.

*Host* — *Glottis nebularia* (Body cavity)

*Locality* — Allahabad

*Cyclocælum mehrii* Khan, 1935

Length 18-28 mm, breadth 3·4-5 mm. Oral sucker very rudimentary. Pharynx muscular 0·27 mm in diameter. Oesophagus S-shaped. Excretory pore posterior and dorso-median. Testes separated from each other by uterine coils; anterior, lateral, and .85 mm  $\times$  0·7-1 mm; posterior in intestinal arc, .9-1.3 mm in diameter. Cirrus sac retort-shaped, extending behind anterior wall of intestinal bifurcation. Genital pore, ventral to middle of pharynx. Ovary 4-6 mm in diameter; shell gland close behind ovary, receptaculum seminis, small pear-shaped inside the ovary. Receptaculum seminis uterum large. Uterus, with well-separated loops, overlapping each at various places. Vitellaria, dense, extending from middle of intestinal bifurcation to excretory bladder. Yolk reservoir small. Ova, thin-shelled, with fully developed miracidia, .12 mm  $\times$  .068 mm.

*Host* — *Capella gallinago gallinago*

*Locality* — ?

*Cyclocælum lobatum* Khan, 1935

Length 13 mm, breadth 2·4 mm. Oral sucker not visible in whole mount. Pharynx muscular, 27 mm in diameter. Oesophagus straight. Excretory pore median and dorso-terminal. Testes separated from each other by uterine coils, anterior testis, lateral and equal in size to the posterior; posterior median, .6-7.5 mm  $\times$  55-7 mm. Genital pore at middle of pharynx. Cirrus sac more or less flask-shaped with tubular anterior end and sac-like posterior part reaching just behind anterior end of intestinal bifurcation. Ovary, .4-5 mm  $\times$  35-55 mm. Shell-gland present. Receptaculum seminis inside the ovary. Receptaculum seminis uterum absent. Uterus between posterior end of shell-gland and intestinal bifurcation. Vitellaria from posterior end of cirrus sac to excretory bladder. Ova, thin-shelled and non-operculate, with fully developed miracidia, .119 mm  $\times$  .068 mm.

*Host* — *Glottis nebularia* (Thoracic cavity)

*Locality* — Allahabad

*Remarks on the genus Cyclocælum* — The species *Cyclocælum sharadi*, *Cyclocælum allhabadi*, *Cyclocælum straightum*, *Cyclocælum capellum*, *Cyclocaelum indicum*, *Cyclocælum mehrii* and *Cyclocælum lobatum* have been described to possess a receptaculum seminis. This structure is not present in the type species of the genus *Cyclocælum*. In view of the opinion already expressed (Lal, 1937) on the systematic value of this character it may be considered desirable to exclude all these species which possess a receptaculum seminis from the genus *Cyclocælum*. It is suggested that a new genus *Receptocælum*, characterised by the presence of receptaculum seminis, may be created for their reception.

Subfamily *Typhlocoelinæ* Harrah, 1922

Under the subfamily *Typhlocoelinæ*, the author discovered a genus *Typhlophilus* Lal, 1936, full details of which have already been published in a previous number of these *Proceedings* (*vide* 1936, 4, No. 1, Sec. B).

Genus *Typhlophilus* Lal, 1936

Distome, with a flat ribbon-like body, and with an extremely feeble funnel-shaped oral sucker and a small muscular ventral sucker Curved prepharynx, globular pharynx and extremely small oesophagus Intestinal cæca, provided with about 10 diverticula on the inner margin, meet in the middle posteriorly to form the Intestinal Bow Excretory bladder crescent-shaped, excretory pore dorsal and sub-terminal Testes, two, in grape-like bunches separated from each other by the first coil of the uterus The anterior testis lies on the left and near intestinal cæcum, the posterior fills the arch near the Intestinal Bow Ovary oval, on the right side at the level of the left testis Ootype, shell-gland and a small receptaculum seminis present between the ovary and the posterior testis Genital pore situated ventral to the intestinal bifurcation, immediately behind the pharynx Eggs small, thin-shelled, without filaments

Type species—*Typhlophilus shovellus*

*Typhlophilus shovellus* Lal, 1936

Ribbon-like and grey coloured trematode, 3.6 mm long and 1.15 mm broad Oral sucker extremely feeble, 1.9 mm × 1.95 mm Ventral sucker circular and muscular, about the middle of the body, .125 mm in diameter Prepharynx 2 mm long, Pharynx thick-walled, 1.9 mm × 2.1 mm Oesophagus extremely small Intestinal cæca provided with 10 diverticula on their inner margin and join posteriorly Excretory bladder 3.5 mm long Anterior testis 1.25 mm × 0.6 mm Posterior testis 1.5 mm × 0.7 mm Cirrus sac 2.5 mm long Ovary at the level of the left testis, .055 mm × 0.7 mm Uterus full of small eggs, eggs measure .02 mm × .01 mm with thin shell and not provided with any polar filament

*Host*—*Spatula clypeata* (Small intestine)

*Locality*—Lucknow

*Remarks on the family Cyclocoelidae*—The retention of the two sub-families Cyclocoeliinae and Typhlocoeliinae by Witenberg (1926) on the basis of cæcal diverticula was questioned by Joyeux and Baer (1927) who regard the cæcal diverticula of only generic importance in the same way as the relative position of gonads The writer (Lal, 1936) has previously shown that the various genera of Cyclocoelidae can be arranged under two distinct groups on the basis of cæcal diverticula Both groups have forms which show variations in the relative position of the gonads, the nature of uterine

coils and the position of genital pore, and thus the presence or absence of caecal diverticula seem to form the natural subdivisions of the family Cameron (1934) and other earlier workers have considered this character in the division of the family *Fasciolidae* into two subfamilies, *Fasciolinae* and *Fasciolopsinae*. It is, therefore, desirable to retain here Witenberg's subdivisions into *Cyclocælinæ* and *Typhlocælinæ*.

The subfamily *Typhlocælinæ* has three distinct genera but, as mentioned by Witenberg (1926), the subfamily *Cyclocælinæ* has got a vast assemblage of forms. Joyeux and Baer (1927) have been rather conservative and do not consider the various genera of Witenberg as valid. They suggest the fusion of all the genera of the subfamily *Cyclocælinæ* into two forms, viz., *Cyclocaelum* and *Spaniometra* which they distinguish by the relative position of the ovary and testes. The genus *Cyclocaelum*, according to Joyeux and Baer, contains all those forms which have their ovary either pre-testicular or intertesticular. Although Witenberg's classification of the family into genera is not free from defects the writer does not agree with Joyeux and Baer in their contention. As already stated the relative position of the gonads has been greatly emphasised in several cases and should here be regarded as a character of at least generic importance. The position of the uterine coils is another character of sufficient importance and combined with the relative position of the ovary merits consideration in establishing the genera of the subfamily *Cyclocælinæ*. Therefore, the members of the subfamily *Cyclocælinæ* can be grouped into four distinct divisions, as follows —

- 1 Ovary in front of the two testes, not separated by uterine coils, e.g., *Hæmatolrephus*  
Other forms are *Wardianum*, *Hæmatoprimum*, *Corpopyrum* and *Uvitellina*
- 2 Ovary in between the two testes separated by uterine coils, e.g., *Cyclocaelum*  
Other forms are *Cycloprimum*, *Harrahium*, *Prohyptiasmus*, *Hyptiasmus*, *Allopyge* and *Transcaelum*
- 3 Ovary behind both the testes, not separated by uterine coils, e.g., *Contracaelum*
- 4 Ovary behind both the testes which are separated by uterine coils, e.g., *Ophthalmophagus*. The genus *Spaniometra* also comes under this

Each division is represented by a well-established genus and the other previously known genera put under each group may be regarded as mere synonyms. Now, there remain only two genera, viz., *Bothriogaster*\* and *Morishitium* which have not been accounted for here. Both of these possess ventral sucker and it would be better to keep them as distinct genera till more information is available about them.

*Diagnosis of the genus Hæmatotrephus Stossich, 1902, emended —*

(Syn *Wardianum* Witenberg, 1926, *Hæmatoprimum* Witenberg, 1926, *Corpopyrum* Witenberg, 1926 and *Uvitellina* Witenberg, 1926)

Cyclocælinæ with flat body, anterior end narrower than the posterior, oral sucker not well developed, subterminal, ventral sucker absent, intestinal cæca smooth, without any lateral projections, extend up to the posterior end of the animal, meeting in the middle line, testes two, almost spherical, lying in the posterior broad end of the animal and not separated by uterine coils, ovary spherical, smaller than testes, always in front of both testes, vitelline glands extend along the intestinal cæca.

*Diagnosis of the genus Cycloælum Brandes, 1892, emended —*

(Syn *Cycloprimum* Witenberg, 1926, *Harrahiun* Witenberg, 1926, *Prohyptiasmus* Witenberg, 1926, *Hyptiasmus* Kossack, 1911, *Allopyge* Johnston, 1913 and *Transcarlum* Witenberg, 1926)

Cyclocælinæ with flat body, anterior end narrower or may be as broad as posterior, oral sucker more or less funnel-shaped, weakly developed, ventral sucker absent, intestinal cæca, smooth without projections, run almost up to the posterior end of animal where they meet together in the middle, testes two, almost spherical, the posterior one lying in the "Intestinal Bow," the anterior further forwards, separated from each other by uterine coils, ovary spherical, smaller than testes, lying always in between the two testes, vitelline glands extend along the intestinal cæca.

*Diagnosis of the genus Contracælum Witenberg, 1926, emended —*

Cyclocælinæ with flat spindle-shaped body, anterior and posterior ends both narrower than the middle, oral sucker quite terminal, ventral sucker absent, intestinal cæca, smooth without any lateral projection, run almost

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\* The name *Bothriogaster* is not available for the generic name since it is preoccupied by *Bothriogaster* Seelivanow, 1879 (Myriapoda). In view of this, the name will have to be changed.

up to the posterior end of the animal where they meet together in the middle; testes two, almost spherical, lying side by side, more or less contiguous and not separated by uterine coils, in the middle of the body, ovary oval, smaller than testes, lying behind both testes in the "Intestinal Bow" vitelline glands extend along the intestinal cæca

*Diagnosis of the genus Ophthalmodragus Stossich, 1902, emended —*

(Syn *Spaniometra* Kossack, 1911)

Cyclocoelinae with flat body, anterior end narrower or as broad as the posterior end, oral sucker weakly developed, ventral sucker absent, intestinal cæca smooth, without lateral projections, run almost up to the posterior end of animal where they meet in the middle, testes two, almost spherical situated in the intercæcal region and separated by intervention of uterine coils, ovary spherical, smaller than the testes, lying always behind both the testes, vitelline glands extend along the intestinal cæca

#### *Family Dicrocoeliidae Looss, 1907*

The family Dicrocoeliidae contains numerous genera and has been a subject of investigation by a large number of workers. The latest comprehensive work is that of Poche (1925) where he has recognised not less than 20 different genera. The main features on which the generic division is based in this family is the relative position of the testes. The distinction and arrangement of the various genera under the family is rather confused and a revision of the family will have to be done. The family Dicrocoeliidae has the following diagnosis —

Trematodes small to medium in size with a more or less elongated, flattened, translucent and non-muscular body. Pharynx and oesophagus present. The intestinal cæca are simple and do not quite reach the posterior end of the body. The excretory bladder is tubular or sac-like. The genital pore is situated in the middle line between the oral and ventral suckers. The testes are situated in level with or behind the ventral sucker and in front of the ovary, opposite to each other or one behind the other. The cirrus sac is small and does not extend behind the anterior margin of the ventral sucker. The ovary is situated behind the testes. The vitelline glands are well developed and are laterally situated, partly overlapping the intestinal cæca. The uterus occupies most of the space behind the genital glands. Eggs relatively small.

Type genus—*Dicrocoelium*.

Among birds in India, the family is represented by three genera:—

1. Genus *Lyperosomum* Looss, 1899
2. Genus *Platynosomum* Looss, 1907
3. Genus *Multivitellaria* Phadke and Gulati, 1930

**Genus *Lyperosomum* Looss, 1899**

Looss created the genus *Lyperosomum* for the reception of *L. porrectum*, *L. longicauda*, *L. strongylosum* and *L. plesiotostomum*. Braun (1901) added three species to the genus, viz., *L. corrigia*, *L. salebratum* and *L. rudentum*. Von Linstow (1906) described *L. squamatum* but this was later removed from the genus by Skrjabin (1913). Looss again (1907) included under the genus, *L. lobatum*, *L. alssoni* and *L. clathratum*, the last one, however, was assigned later to the genus *Platynosomum*. Skrjabin (1913) added *L. filiforme*. Nicoll (1914) described *L. scitulum* and *L. direptum* of which the latter was transferred later to the genus *Oswaldoia* by Travassos (1919). Johnston (1917) described three species *L. parvum*, *L. megastomum* and *L. harrisoni*. In the same year, Travassos (1917) added *L. obliquum*, *L. transversum*, *L. rarum*, *L. lari* and *L. sinuosum*. Isaitschicoff (1919) described *L. domicum* and *L. attenuatum*. Layman (1922) added three species *L. magnitestium*, *L. vanellicola* and *L. transverso-genitalis*. The same author (1923) described *L. fringillæ* and again (1926) *L. lanicola*, *L. asowi*, *L. loossi* and *L. alaudæ*. Baylis (1927) transferred *Distoma vitta* as *L. vitta*. The latest comprehensive work is that of Skrjabin and Udzinew (1930) who also described a new species *L. papabejani* and besides have given a useful key for the identification of the various species. Price (1935) described a peculiar species *L. monenteron* which shows only a single intestinal cæcum. He thinks that probably this condition of the intestine may be present in some other species. The writer considers this feature as very important and thinks that such forms should not be included in the genus. In fact, it appears necessary to create a separate genus for the form described by Price.

**Diagnosis of the genus *Lyperosomum* Looss, 1899.—**

*Dicrocoelidae*—Body elongated ribbon-shaped, spherical in section. Testes tandem behind the ventral sucker. Vitellaria behind the testes. Other characters as of the family.

From India two species have so far been described under the genus, one by Bhalerao (1926) and the other by Patwardhan (1935).

*Lyperosomum kakea* Bhalerao, 1926

Body elongated, tapering at both ends, cuticle without spines Length 3.36 mm. and breadth (maximum at the level of ventral sucker) 33 mm. Oral sucker terminal, .13 mm x 15 mm Ventral sucker, situated at 1/5th of the distance from the anterior end, measures .2 mm in diameter Pharynx absent Pharynx, globular, measuring .06 mm \* in diameter Intestinal caeca up to the posterior end of body Testes, oval, one behind the other some distance behind ventral, sucker placed centrally with their axes oblique and measure 15.18 mm x 12-.125 mm Genital pore some distance behind pharynx Cirrus sac pear shaped, lies centrally, about .28 mm anterior to ventral sucker and contains a coiled vesicula seminalis Para prostatica, ductus ejaculatorius and cirrus small Ovary ovoid, behind testes, in central line and measures 1.65 mm x 1.2 mm Receptaculum seminis immediately behind it Laurer's canal present Shell-gland, post-ovarial Uterine coils fill up posterior part of body behind the ovary Vitellaria small, extending a little behind ovary. Eggs, oval, operculate measuring 0.28-.03 mm x 0.16-.018 mm

*Host* — *Corvus insolens* (Liver)

*Locality* — Rangoon

*Lyperosomum colorosum* Patwardhan, 1935

Body elongated, tapering at both ends and measures 1.7-3.0 mm in length. Maximum breadth 1.92-.34 mm at the level of acetabulum Integument smooth, parenchyma with scattered pigment particles Oral sucker, subterminal, elliptical, .076-.134 mm x .092-.16 mm Pharynx muscular and spherical, 0.43-.075 mm in diameter Oesophagus 0.0-.1 mm long Intestinal caeca extend up to 4/5th of the worm posteriorly Acetabulum 1.38-.24 mm in diameter, and is 3.50-.63 mm behind the anterior end of the body Testes, two, post-acetabular, one behind the other Anterior testis spherical 1.27-.22 mm in diameter Posterior testis, oval, separated from anterior by a uterine loop and measures .108-.208 mm, 1.23-.217 mm Genital pore midway between acetabulum and anterior end of body Cirrus pouch elongated, pyriform 1.2-.21 mm x 0.4-.07 mm It contains large vesicula seminalis Ovary spherical, smaller than testes, .04 mm behind posterior testis, in the median line It measures 0.84-.118 mm in diameter Receptaculum seminis dorsal and lateral to ovary and measures 0.23-.04 mm in diameter Shell-gland is similar in position but slightly ventral Vitellaria, post-ovarial, in two lateral rows of 6-7 follicles on each side Uterus extends backwards as far as posterior end of body Eggs large, elliptical, thick-shelled and measure .0125—.022 mm x .025—.04 mm

*Host* — *Temenuchus pagodarum*

*Locality* — Nagpur

Key for the identification of the species of *Lyperosomum* \*

Ovary larger than both testes—*L. kakea*

Ovary smaller than both testes—*L. colorosum*

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\* In the original paper it is mentioned as .6 mm. which is probably a misprint.

Genus *Platynosomum* Looss, 1907

The genus *Platynosomum* was created by Looss (1907) for a trematode, obtained from *Circatus gallicus*, which he named *P. semifuscum*. Later on several authors added to this genus. Kossack (1910) described *P. fastesum*, Nicoll (1915) recorded *P. acuminatum* from Kestrel and also transferred two species of *Dicrocælum* as *P. deflectens* and *P. petiolatum*. Travassos (1916) added *P. microchis* and later again (1918) *P. arietis*. Tubangui (1928) reported *P. philippinerum*. The latest work on the genus is that of Cameron (1928) where he described *P. planicipites* from a tiger cat.

Diagnosis of the genus *Platynosomum* Looss, 1907 —

*Dicrocælidae* — Body lancet-shaped, greatest width at the level of the testes. Anterior end more pointed than posterior. Suckers almost of equal size. Testes symmetrical, at equal height behind ventral sucker. Cirrus sac plump, sac-shaped. Ovary lies behind the testes. Other characters as of the family.

The only form recorded from India is *P. acuminatum* by Bhalerao (1926) which was previously obtained by Nicoll (1915) from Kestrel in Scotland.

*Platynosomum acuminatum* Nicoll, 1915

*Host* — *Corvus insolens* (Liver)

*Locality* — Rangoon

*Remarks* — Bhalerao gives no description or figure but mentions that the only variations from Nicoll's description, that he finds in his specimens, are in the dimensions of the body and the posterior extension of vitellaria. Since the writer has no specimens, he cannot add any observations on the subject. A summary of Nicoll's description is, however, given below —

Length 6.3 mm., maximum breadth just behind ventral sucker is 1.5 mm. Oral sucker twisted to right, .45 mm. x 40 mm. Ventral sucker is 6 mm. x .75 mm. situated 1.97 mm. from the anterior end. Pharynx contiguous with oral sucker and measures 1.7 mm. x 1.5 mm. Oesophagus short. Intestinal diverticula long and narrow. Genital pore over the pharynx, twisted to right. Cirrus pouch .7 mm. x .18 mm. contains vesicula seminalis, pars prostatica and ductus ejaculatorius. Testes symmetrical, immediately behind ventral sucker and measure 2.5 mm. x 3.6 mm. Ovary behind left testis, oval. Vitellaria lateral, between level of testes, and 2.8 mm. from posterior end, follicles small. Uterus fills up greater portion of post-acstibular space; convolutions entirely confined behind ventral sucker. Vagina weakly developed. Eggs numerous, measure .033-.039 mm. x .018-.02 mm.

Genus *Multivitellaria* Phadke and Gulati, 1930

Body thick and opaque, ventrally convex Pharynx present Ovary post-testicular and median above the fork of the excretory bladder Testes lateral and lying under the cæca Twenty-eight pairs of vitellaria lying exterior to the cæca Follicles of the vitelline glands tubular Genital pore sucker-like close to and in front of the acetabulum and lying behind the gut-fork Excretory bladder Y-shaped

Type-species—*Multivitellaria hewletti*

*Multivitellaria hewletti* Phadke and Gulati, 1930

Body thick and opaque and ventrally convex Length 6.0-16.6 mm, breadth 4.0-8.7 mm. Oral sucker smaller and less prominent than acetabulum. Pharynx present Oesophagus 5 mm long; intestinal cæca, straight or slightly curved in a zigzag manner Testes, two, lateral, pro-ovarial, lying under the cæca Longitudinal sections of the fluke showed the presence of seminal vesicle and pars prostatica in close proximity of the cirrus sac Genital pore, sucker-like, close to and in front of acetabulum, and lying behind the intestinal fork Ovary, situated medially adjacent to shell-gland, rectaculum seminis, and Laurer's canal Vitellaria, 28 pairs, lying exterior to cæca Excretory bladder Y-shaped. Uterus with loops; eggs 78-88 $\mu$  by 34-57 $\mu$ .

*Host*—*Corvus splendens* (Gall bladder)

*Locality*—Bombay

*Remarks*—This form shows the usual characters of the family Dicrocoeliidae but differs from all the genera in possessing a thick and fleshy body, much greater extension of the vitellaria, and a sucker-like genital pore The writer, therefore, fully agrees with the authors in regarding this form as a distinct genus Phadke and Gulati have also suggested a new subfamily Multivitellarinae for the reception of this form

Key for the identification of Avian genera of the family Dicrocoeliidae reported from India

- |  |                        |
|--|------------------------|
| 1. Testes tandem . . . . .   | <i>Lyperosomum</i>     |
| Testes connubial .. . . .  | 2                      |
| 2. Vitellaria extend throughout the body length—genital sucker present . . . . . | <i>Multivitellaria</i> |
| Vitellaria confined to the middle of the body—genital sucker absent .. . . . .   | <i>Pidlynosomum</i> .  |

## Family Opisthorchidae Braun, 1901

The family Opisthorchidae contains about a dozen genera and attempts were made to divide the family into subfamilies but Morgan (1927) has pointed out the undesirability of this course of action owing to absence of any constant differences. Further, Morgan (1927) has suggested the synonymy of *Notaulus* to *Opisthorchis* and the writer agrees with him. In fact several other genera, *viz.*, *Amphimerus* and *Cyclorchis* which are recognised by Morgan as distinct from *Opisthorchis* also do not show those distinctive features which should be taken as characters of generic importance. Morgan (1927) further suggests the fusion of the genera *Clonorchis* and *Opisthorchis* on the basis of the branching of the testes but the writer thinks that the difference in the excretory bladder in the two cases is rather much pronounced. It would, therefore, be desirable to keep the two genera as distinct. Recently Yamaguti (1933) described a genus *Oesophagicola* from the oesophagus of a marine snake and created a new subfamily Oesophagicolinae for its reception, under the family Opisthorchidae. The genus, in question, no doubt shows important differences from the members of the family Opisthorchidae with which it resembles in the absence of a cirrus sac and the relative position of the gonads. It is, however, not possible, for the writer at present to make any comments on the systematic position of this genus.

*Diagnosis of the family Opisthorchidae* Braun, 1901, emended Morgan, 1927 —

Body flat and transparent, sometimes much thickened, narrowing anteriorly. Suckers near each other (except in *Microtrema*), often only moderately developed or atrophied. Pharynx present and usually followed by a short oesophagus. Intestinal cæca long and unbranched, not always reaching the posterior end. Excretory vesicle Y-shaped with proportionately long stem and short branches, opening at the posterior end or on the ventral surface in the region of the testes. In the former case the stem winds S-shaped between the testes or may lie dorsal to the testes. The genital opening is immediately in front of the ventral sucker. A cirrus sac is absent. The testes lie near the hind end of the body, obliquely or directly behind one another, sometimes they lie laterally. They are simple, lobed or dendritic. The ovary lies immediately in front of the testes and may be simple, lobed or multilobed. Laurer's canal present, receptaculum seminis usually strongly developed. Vitellaria moderately well developed, divided into acini or continuous and lie between the cæca and the margins of the body. Uterine folds in front of the testes and mostly in front of the ovary,

extending to or in front of the ventral sucker Eggs numerous, small and light-brown in colour In the gallbladder and bile ducts of mammals, birds, reptiles and fish

The family is represented among birds in India by a single genus *Opisthorchis*

**Genus *Opisthorchis* Blanchard, 1898**

A very large number of species have been described under the genus and their diagnostic characters are based on the nature of the cuticle, ratio of oral to ventral sucker, disposition of the gonads, nature of the excretory bladder, the position of the ventral sucker, etc. In fact, there are some species which do not show any clear differentiation and will probably be proved as synonymous. But in the present state of our knowledge and also in the absence of data on the life-history, it is not possible yet to suggest any change in their nomenclature, although Price (1932), on morphological grounds alone, has emphasised the identity of several species.

Morgan (1927) described *O. dendriticus* from the liver of a Sarus crane, *Antigone* imported into the London Zoological Gardens from India. The writer has been able to collect two species of the genus from the avian hosts in India, and although he is fully aware of the undesirability of multiplication of species he finds it necessary to do so as the specimens collected present certain important differences from the existing species of the genus. They are, therefore, being described here as new species. The diagnosis of the genus *Opisthorchis* given by Morgan (1927) is also slightly emended.

***Diagnosis of the genus Opisthorchis emended —***

*Opisthorchidae*, body distinctly, often very greatly elongated, sometimes pear-shaped, anterior end attenuated, posterior end broader. Skin generally smooth. Excretory vesicle usually Y-shaped with long sigmoid stem winding between the testes or passing dorsal to them. Copulatory organs absent. Testes in the posterior portion of the body, and placed either obliquely or directly behind one another. Ovary simple or lobed. Laurer's canal present. Receptaculum seminis prominent. Uterine coils extend from the ovary to the ventral sucker, sometimes slightly overlap the intestinal cæca. Vitellaria moderately developed, lateral of the intestinal cæca and not extending anterior of the ventral sucker, ending posteriorly at the level of the ovary. Vitellaria do not always form one region.

Type species—*Opisthorchis felinus*.

*Opisthorchis guddhis n. sp. (Figs 1 and 2)*

About a dozen specimens of this trematode were obtained from the liver of *Sarcogyps calvus* shot by the writer in Badshahbagh, Lucknow. The parasites appeared pink in fresh condition and their anterior end was very contractile and movable.

The body is more or less pear-shaped, and measures 3.9 mm  $\times$  1.5 mm. The oral sucker is ventro-terminal and measures 1.5 mm  $\times$  2 mm. The ventral sucker lies at a distance of 1.275 mm from the anterior end and measures 1.75 mm  $\times$  2 mm. The mouth leads into a short prepharynx 0.5 mm in length. The pharynx is elliptical and measures 1.5 mm  $\times$  1.1 mm. The oesophagus is thick-walled and measures 3 mm in length. The intestinal cæca extend almost up to the posterior end of the body.

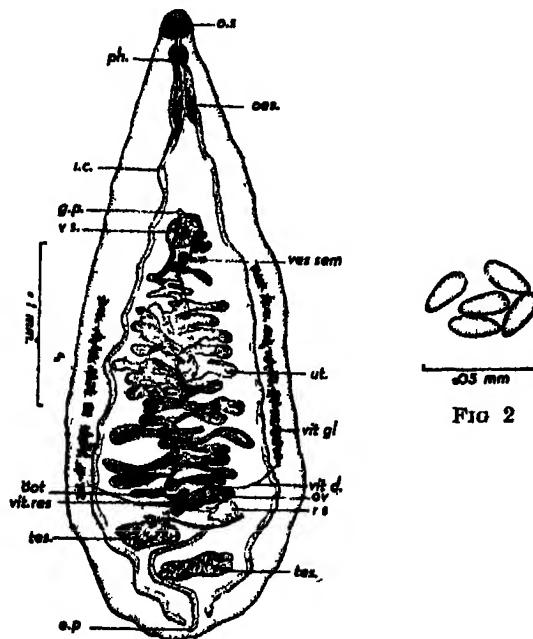


FIG. 1

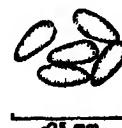


FIG. 2

FIG. 1.—*Opisthorchis guddhis* n. sp., entire worm—dorsal view.

FIG. 2.—*Opisthorchis guddhis*—eggs

The excretory bladder is V-shaped and opens by the excretory pore at the postero-dorsal end of the body. The median stem of the 'V' passes in between the testes and bifurcates into the lateral horns between the anterior testis and the receptaculum seminis.

The testes are ovoid bodies with notched margin and lie obliquely one behind the other at the posterior end of the body. The anterior testis which lies on the left side measures  $.4\text{ mm} \times 15\text{ mm}$  The posterior testis measures  $.475\text{ mm} \times 16\text{ mm}$  The vasa deferentia unite to form a coiled vesicula seminalis in the region of the metraterm. The vesicula seminalis runs along the right margin of the ventral sucker and opens immediately in front of it at the genital pore.

The ovary is an elongated, flattened, transversely placed body measuring  $42\text{ mm} \times 1\text{ mm}$  A well-developed receptaculum seminis lies behind the ovary and measures  $2\text{ mm} \times 15\text{ mm}$  The duct from the receptaculum seminis forms a loop near the left end of the ovary before entering the ootype. A small oviduct leads from the ovary to open into the ootype which lies in front of the ovary and is surrounded by small unicellular shell-glands.

The vitellaria consist of small follicles which stretch extra-caecally in the region of the uterus. The vitelline zone on the left side is broken up into groups while on the right side it is more or less continuous except for a slight anterior part. The transverse vitelline ducts run in front of the ovary and meet to form a very small yolk reservoir from which a small duct opens into the ootype.

The uterus arises from the left of the ootype and runs forward in peculiar transverse loops. It ends in an elongated metraterm and opens in front of the ventral sucker. The eggs are numerous but small and measure  $.0225\text{ mm} \times .01\text{ mm}$

**Remarks**—This form differs from all the known species of the genus *Opisthorchis* in having a peculiarly thick-walled oesophagus. The nearest ally of this form is *O. obsequens* from which it differs in possessing distinct prepharynx, very feebly lobed testes, nature and extent of vitellaria and much smaller eggs. It is, therefore, regarded as a new species.

#### *Opisthorchis cheelis n. sp. (Figs 3 & 4)*

A large number of these trematodes were collected by Dr G S Thapar from the liver of the common kite, *Milvus migrans*. The body of the animal is elongated and leaf-like and measures  $6.8\text{ mm.} \times 1.5\text{ mm.}$  The cuticle is thin and sparingly spinose, specially in the anterior half of the body.

The oral sucker is terminal and measures  $.2\text{ mm}$  in diameter. The ventral sucker which lies at a distance of  $1.65\text{ mm.}$  from the anterior end is  $.2\text{ mm.} \times 15\text{ mm}$  in size.

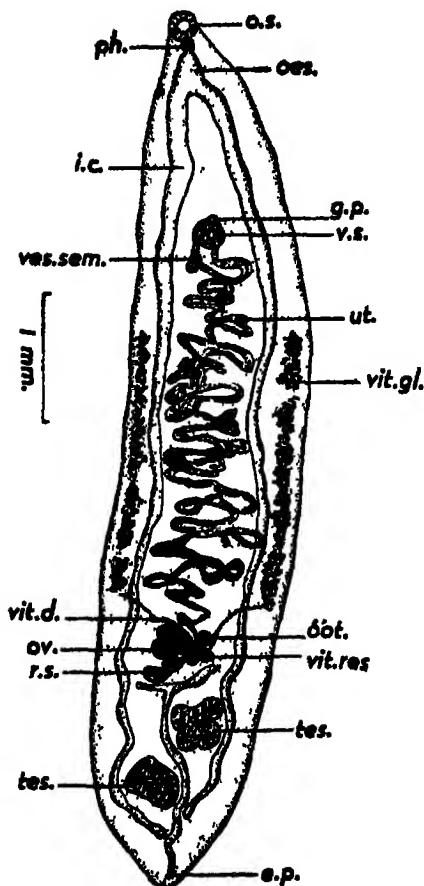


FIG. 3

FIG. 3.—*Opisthorchis cheelis* n. sp., entire worm,—ventral view Body spines not shown

FIG. 4.—*Opisthorchis cheelis*—eggs.

The mouth leads into an extremely small prepharynx which is followed by a globular pharynx .095 mm x .085 mm in size. The oesophagus is thin-walled and measures .3 mm. The two intestinal cæca extend upto the posterior end of the body.

The excretory bladder is Y-shaped. The median stem is not S-shaped but slightly sinuous and runs in between the two testes. It divides into the two horns just behind the receptaculum seminis. The excretory pore is dorsal and terminal.



FIG. 4

The two testes are obliquely placed behind each other. The anterior testis which is situated slightly towards the left is four-lobed and measures 48 mm  $\times$  42 mm. The posterior testis is ovoid and measures 4 mm  $\times$  3 mm. The vasa deferentia unite to form the vesicula seminalis which is very slightly coiled and runs along the right border of the ventral sucker to open at the genital pore which lies immediately in front of it.

The ovary is somewhat bilobed and median in position. It measures 4 mm  $\times$  275 mm. The receptaculum seminis is an elongated body, slightly constricted in the middle and lies immediately behind the ovary. It measures 3 mm  $\times$  1 mm. A small duct leads from the ovary into the ootype which is situated a little to the left of the ovary and is surrounded by unicellular shell-glands.

The vitellaria are more or less continuous follicles, extra-caecal, and lie in the middle region of the body. The vitelline zone on the right side is slightly smaller than the left. The vitelline ducts from the two sides run backwards in the form of a 'V' and meet to form a very small yolk reservoir from which a narrow duct leads into the ootype.

The uterus arises from the right side of the ootype and runs forward in inter-caecal transverse loops and opens at the genital pore immediately in front of the ventral sucker. It contains a large number of eggs which measure 0.25 mm  $\times$  0.1 mm.

*Remarks*—This species differs from all the existing species of the genus except *O. viverrini*, *O. piscicola*, *O. caninus*, *O. noverca* and *O. pedicellata* in having its cuticle armed with minute and sparingly arranged spines.

From *O. viverrini* it differs, however, in having the oral sucker slightly larger than the ventral, much longer oesophagus, slightly lobed ovary, disproportionately developed vitellaria and smaller eggs.

From *O. piscicola* it differs in having the ventral sucker smaller than the oral, oblique position of testes, disproportionate vitellaria confined to almost middle third of the body, and in having larger eggs.

From *O. caninus* it differs in having a non-pedicled ventral sucker situated at double the greater distance from anterior end, a very small prepharynx, much longer oesophagus, extension of intestinal caeca up to the posterior end, more or less straight (not coiled) vesicula seminalis, very slight lobation of ovary, elongated and post-ovarian receptaculum seminis and the non-pedicled genital pore.

From *O. noverca* it differs in having a very long oesophagus, extension of intestinal caeca to the posterior end, anterior testis lobed and posterior

with almost entire margin, ovary ahead of the horns of the excretory bladder, much smaller range of vitellaria and much smaller eggs

From *O. pedicellata* it differs in having smaller ventral sucker, non-pedicled genital pore, absence of looped terminal ends of the male and female ducts, extra-cæcal vitellaria, elongated receptaculum seminis and smaller eggs

Key for the identification of the avian species of the genus *Opisthorchis* reported from Indian hosts

- |   |  |                       |
|---|--|-----------------------|
| 1 | Vitellaria in middle of body,<br>testes slightly lobed                 | 2                     |
|   | Vitellaria confined to posterior<br>half of the body, testes dendritic | <i>O. dendriticus</i> |
| 2 | Oesophagus thickwalled, cuticle<br>non-spiny                           | <i>O. giddhis</i>     |
|   | Oesophagus thinwalled, cuticle<br>spiny                                | <i>O. cheelis</i>     |

#### Family Lecithodendriidae Odhner, 1910

Owing to the close affinities between Lecithodendriinae and Pleurogenetinae, Odhner (1910) created the family Lecithodendriidae for their reception. This has not been questioned, but some confusion has been created about the grouping of genera into subfamilies. It may be pointed out here that this is not based on any definite grounds and apparently different characters have been considered in this connection, e.g., the length of the intestinal cæca, the extent of the vitellaria and the position of the testes as well as the position of the genital pore and the host-relationship.

Mehra (1935) attached undue importance to trivial characters and thus added confusion by further dividing the family Lecithodendriidae into six subfamilies, viz., Anchitreminae N Subfam Lecithodendriinae, Pleurogenetinae, Phaneropsolinae N Subfam, Exotidendriinae N Subfam, and Eumegacetinae N Subfam. On a review of his work it appears that too much stress has been laid on the posterior extension of intestinal cæca and position of cirrus sac or on the median or lateral position of the genital pore.

The present writer considers that all these features show variations in the family and should not form the basis of subfamily divisions. The only character which appears to be constant is the cirrus sac. It is either present or absent. The presence or absence of cirrus sac should, as has already been discussed (Lal, 1937), form a character of subfamily importance.

It is, therefore, considered desirable to keep only two subfamilies, viz., Lecithodendriinae with forms in which the cirrus sac is absent and Pleurogenetinae containing forms which possess a cirrus sac. The various subfamilies of Mehra can easily be accommodated under these two heads. Much emphasis has been laid on keeping the genus *Ganeo* in the subfamily Pleurogenetinae although it lacks a cirrus sac. The chief argument advanced is the position of the genital pore which is sinistral in *Ganeo* as in other Pleurogenetinae while it is median in Lecithodendriinae. The writer considers that the shifting of the genital pore from median to marginal position in about the same level is not a character of subfamily importance, at any rate, certainly not of a greater significance than the presence or absence of a cirrus sac. It would, therefore, be desirable to transfer the genus *Ganeo* to the subfamily Lecithodendriinae as suggested earlier by Travassos (1930).

*Diagnosis of the family Lecithodendriidae* Odhner, 1910 —

Digenea, with variable shape of body. Body spines either present or absent. Ventral sucker at about the middle of the body. Pharynx, oesophagus and intestinal cæca of variable length. Excretory bladder V- or Y-shaped. Testes generally symmetrical, sometimes, close together, at variable level in the body. Cirrus sac present or absent. Ovary, dorsal, mostly dextral, at varying levels of the body. Receptaculum seminis small. Laurer's canal present. Vitellaria situated on either side, branched follicles, dendritic mostly in front of the middle body. Uterus well-developed, with regular loops, mostly pressed to the hinder end of the body. Genital pore in the anterior part of the body, median or left-sided and sometimes dorsal. Eggs numerous, small. Parasitic in intestine of Mammals, Birds, Reptiles and Amphibia.

The family is divided into two subfamilies —

1. Lecithodendriinae—without a cirrus sac.
2. Pleurogenetinae—with a cirrus sac.

The only avian species under this family reported so far from India comes under the subfamily Pleurogenetinae as it possesses a cirrus sac.

*Genus Parabascus* Looss, 1907

(Syn. *Pleuropsolus* Mehra, 1935)

*Diagnosis* — Body small, about 1 mm. long with blunt ends. Skin strongly and thickly spinose. Oral sucker subterminal, globular. Acetabulum almost pre-equatorial, about twice as large as oral sucker. Pharynx small, oesophagus long. Cæca extend post-testicular. Excretory pore

caudo-terminal. Copulatory organ muscular Cirrus sac large, thick, club-shaped, extends to left around acetabulum Ductus ejaculatorius, pars prostatica and prostatic cells present Genital pore at the side of acetabulum Testes two, large, oval, post-acetabular Ovary elongate pre-testicular, right of median line Shell-gland post-acetabular Vitellaria chiefly pre-acetabular. Uterine coils broad, almost entirely post-acetabular Eggs numerous, light-brown and operculate

*Parabascus insolens* (Bhalerao, 1926)

(Syn *Phaneropsolus insolens* Bhalerao, 1926 ,

*Pleuropsolus insolens* Mehra, 1935)

Body pear-shaped, cuticle covered with spines Length 585-·73 mm Breadth 29-·365 mm , maximum being at the level of testes Oral sucker 113 mm  $\times$  1 mm Ventral sucker smaller than oral, ·1 mm in diameter Pharynx, globular, muscular ·03-·035 mm in diameter Intestinal circa short and somewhat anterior to the testes Testes, oval with entire margins, lie symmetrically, and measure 0·097-0·12 mm  $\times$  0·7-·093 mm Cirrus sac, zigzag or often horse-shoe-shaped It is dorsal to ventral sucker, partly anterior to it, lying between it and the intestinal fork On its posterior side it contains a large vesicula seminalis and pars prostatica Ductus ejaculatorius small followed by fairly long muscular penis capable of protrusion through genital pore, situated immediately anterior to the ventral sucker, on the left side of middle line. Ovary oval, measures ·6-7 mm  $\times$  ·04-·05 mm , right of the ventral sucker and is often overlapped by the right testis Shell-gland behind ventral sucker in the central line Receptaculum seminis varies in size It lies on the inner side of the right testis Lauder's canal present Uterus long, coils mostly post-testicular Eggs, brown, operculated, 0·18-·022 mm  $\times$  0·07-·0105 mm The vitellaria are situated at the sides of or overlapping intestinal coils, follicles, small, 8-12 on each side Excretory pore at the hind end of body leads into V-shaped bladder whose arms diverge and end slightly behind testes

*Host* —*Corvus insolens* (Intestine)

*Locality* —Rangoon

*Remarks* — Bhalerao (1926) described this species under the genus *Phaneropsolus* Mehra (1935), on small size of cirrus sac and acetabular position of genital pore, suggested the creation of a new genus *Pleuropsolus* for it. On looking through the figure given by Bhalerao it appears that the size of the cirrus sac is not small but owing to its bent character, it does not extend beyond the intestinal bifurcation The position of the genital pore in the present form is pre-acetabular and this is certainly different from the position of genital pore in *Phaneropsolus* where it is far forwards just behind the pharynx The present form also resembles the genus *Parabascus* in the shape of cirrus sac, the pre-acetabular position of genital pore, in the

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\* In the original account it is " 0·97-0·12 mm " which evidently is a misprint.

extent of vitellaria and in the position of the excretory pore It differs, however, from *Parabascus* in having shorter intestinal cæca, smaller ventral sucker and an avian host-features which are not of very great importance.

It is true that the species should be removed from the genus *Phanerop-solus*, but it should not be taken as a basis for the creation of a new genus *Pleuropsolus* as suggested by Mehra (1935) It is suggested to place it under the existing genus *Parabascus* with which it resembles in many important points discussed before

#### *Family Heterophyidae* Odhner, 1914

Odhner (1911) suggested the name *Heterophyidae* to replace the older names *Cotylogomimidae* and *Cænogomimidae* Ciurea divided the family into five subfamilies, viz., *Heterophyinae*, *Metagonomiminae*, *Centrocestinae*, *Apophallinae* and *Cryptocotylinae* This division has subsequently been modified by Nicoll (1923), Faust and Nishigori (1924), Poche (1925) and Witenberg (1926) The family *Heterophyidae* as it stands to-day has the following diagnosis —

Minute forms, usually not exceeding 2 mm in length Anterior portion of body thinner and more movable than the posterior portion Skin covered with small scale-like spines that are reduced posteriorly and may even disappear towards the posterior end of the body Intestinal cæca simple, usually extending to the posterior end of the body Genital pore in the immediate neighbourhood of the acetabulum, genital ducts usually open into a genital sinus, which may be variously modified and contains a cirrus-like body or gonotyl (genital sucker) Acetabulum usually median but may be displaced to the right of the median line, sometimes it is partially or completely atrophied and enclosed in the genital sinus Cirrus sac absent, seminal vesicle well developed, U- or S-shaped, the vas deferens surrounded proximally by a mass of prostatic cells Testes two or one, oval, globular, or slightly lobed, near the posterior end of the body, side by side, or obliquely one in front of the other Ovary oval, globular or slightly lobed, generally pre-testicular sometimes post-testicular usually to the right of the median line Seminal receptacle and Laurer's canal present near the ovary, usually near its posterior border Vitellaria, mainly in the lateral fields, may extend anteriorly to or beyond the genital aperture Uterus usually restricted to the intercæcal field between the ovary and genital pore, but may extend to posterior end of body Adults parasitic in the intestine of birds and mammals.

Type genus—*Heterophyes* Cobbold, 1866.

Only one genus *Ascocotyle* of the family Heterophyidae has been reported from birds in India.

*Ascocotyle* Looss, 1899, emended Srivastava, 1935

**Diagnosis** —Minute distomes, body thickly spinose, oral sucker armed with a single or double crown of straight cylindrical spines. Oral sucker continued posteriorly into a distinct appendage, prepharynx long, pharynx well developed and muscular, oesophagus present or absent, intestinal cæca long or short. Acetabulum median, situated in association with the genital sinus in a depression of the ventral body surface. Testes situated one on each side at the hinder end of body, vesicula seminalis and ejaculatory duct well developed. Cirrus sac is absent. Ovary median or slightly to one side, pre-testicular, receptaculum seminis large, situated in level with ovary or behind it. Vitellaria lateral, usually post-acetabular sometimes extending as far forward as the pharynx and meeting mesially near the intestinal bifurcation. Uterus usually post-acetabular, rarely extending as far forward as the pharynx, eggs large, operculate, measuring 0.015–0.035 mm × 0.008–0.017 mm in size. Parasitic in birds and mammals.

The only avian species recorded from India is *Ascocotyle intermedius* Srivastava, 1935.

Body pyriform, 6–9 mm × 2–3.8 mm in size with backwardly directed spines. Oral sucker terminal, 0.1–0.5 mm in diameter, surrounded by double crown of cylindrical spines about 28–30 in number. Ventral sucker female, 0.66–0.77 mm in diameter, in middle of body, lying together with the genital pore in a shallow depression—the ventrogenital sinus. Genital opening guarded by the gonotvis. Excretory pore terminal. Oral sucker has an oral cæcum, which lies dorsal to prepharynx. Prepharynx long. Pharynx 0.3–0.4 mm × 0.2–0.3 mm. Oesophagus short. Intestinal cæca terminate in level with the anterior margin of ovary. Testes, posterior, symmetrical, measure 1.2–1.7 mm × 0.7–1.2 mm. Vesicula seminalis, enormous, retort-shaped. Cirrus sac absent. Ejaculatory duct joins with uterus forming a genital sinus. Ovary between right testis and ventral sucker irregular and measures 0.8–1 mm × 1.1–1.4 mm. Receptaculum seminis, yolk reservoir and Laurer's canal present. Vitellaria extend up to pharynx. Uterus never extending beyond genital sinus. Eggs, operculate, 0.3–0.35 mm × 0.15–0.17 mm.

**Host** —*Haliætus leucoryphus* (Intestine)

**Locality** —Allahabad.

**Remarks** —The genus *Ascocotyle* was created by Looss in 1899. Faust (1920) described the genus *Phagicola* but subsequently (1926) considered it as a species of *Ascocotyle*. Meanwhile Stunkard and Haviland (1924) split up the genus *Ascocotyle* into two sub-genera *Ascocotyle* and *Parascocotyle*.

Witenberg (1929) recognized *Parascocotyle* of Stunkard and Haviland and suggested that a redescription of new material of *Phagicola pithecophagica* could settle the question whether *Parascocotyle* is synonymous with *Phagicola* or they both are valid genera. Price (1935) proved the identity of *Phagicola* and *Parascocotyle* and considered that *Phagicola* and *Ascocotyle* should be regarded as distinct genera, differing from each other in the arrangement of spines on the collar in one or two rows, presence or absence of oesophagus, length of intestinal cæca, position of vitellaria and the extent of the uterus. Srivastava (1935) in describing a species *Ascocotyle (Phagicola) intermedius* has pointed out that this species connects the two genera of Price as regards the extent of vitellaria. He has, therefore, regarded *Phagicola* and *Ascocotyle* as sub-genera of *Ascocotyle* and based the separation of the species *Ascocotyle intermedius* under the sub-genus *Phagicola* on the grounds that it possesses a long oesophagus, long intestinal cæca, and has its uterus confined behind genital sinus. This does not appear to be sound. In fact in his description Srivastava says (page 271), "The wide intestinal cæca are moderately long". In his diagram of the species a few eggs are shown a little ahead of the region of the genital sinus. There appears, therefore, to be some confusion in the matter. Owing to the arrangement of oral spines the extent of vitellaria and spination of the body, Price (1936) still holds that the sub-genera *Ascocotyle* and *Phagicola* should be given a generic status. There is, in fact, a great deal of variability in the extent of vitellaria and in the size and extent of oesophagus and intestinal cæca throughout the genus, and in the absence of constant characters, the writer considers that this differentiation into genera and sub-genera be abandoned.

#### *Family Microphallidae* Travassos, 1920

Ward (1901) created a subfamily *Microphallinae* for the reception of the two genera *Microphallus* and *Levinsenella* and kept it close to the sub-families *Brachycotylinae* and *Pleurogenetinae*. A few other isolated genera, viz., *Monocæcum* Stafford, *Spelotrema* Jagerskiold, *Spelophallus* Jagerskiold and *Maritrema* Nicoll were added to this subfamily. Odhner (1911) transferred the subfamily *Microphallinae* to the family *Heterophyidae* and was supported by Nicoll (1924), Poche (1926), Fuhrmann (1928), Stunkard (1929), Faust (1929) and Sprehn (1932). Other workers, viz., Ransom (1920), Ciurea (1924), Viana (1924), Witenberg (1929) and Müller and Van Cleave (1932) emphasized its exclusion from *Heterophyidae*. Travassos (1920) while agreeing with these latter workers raised it to the status of a family *Microphallidae*, to which view the present writer fully subscribes.

The family *Microphallidae* as it stands to-day has the following diagnosis —

Trematodes, with small oval or elliptical or pear-shaped or conical body with blunt apex Oral sucker, terminal or subterminal Ventral sucker situated in the mid-body or hind-body Pharynx present, prepharynx present or absent Oesophagus long, intestinal cæca, with one cæcum sometimes longer than the other, very short and never reaching behind ventral sucker Excretory bladder V-shaped Genital opening either adjacent or away from the ventral sucker, often provided with a genital atrium which may have sometimes thimble-shaped pockets on its lateral walls Cirrus sac present or absent Pars prostatica lying free or covered when cirrus sac present. Vitelline glands, in separate follicles either in groups or irregular or in the form of a horse-shoe-shaped band Testes behind ovary, the two testes are almost on the same level Ovary near the acetabulum Receptaculum seminis absent Laurer's canal present Uterus fills up the posterior broad portion of the body Eggs, small and numerous.

Type genus—*Microphallus*

Only one genus of the family, viz., *Levinseniella* has been reported from India

Genus *Levinseniella* Stiles and Hassall, 1901

*Diagnosis* —*Microphallidae*, excretory bladder small and not reaching up to testes. Vitellaria in groups of 7-8 follicles on each side Genital pore close to the ventral sucker Genital atrium shows pocket-like thickenings There are always four thimble-shaped papillæ associated with the male apparatus The "Female papillæ" are thin-walled, between the ventral sucker and the male atrium

Type species—*Levinseniella brachysoma*

*Levinseniella indica* Lal, 1936 \*

Body roughly triangular, covered over with minute spines upto the level of the ventral sucker, measures 93 mm × 5 mm Oral sucker .1 mm × 12 mm Ventral sucker 08 mm × 078 mm Prepharynx .02 mm long Pharynx .056 mm × 055 mm Oesophagus 22 mm long. Right testis 105 mm × 058 mm Left testis .12 mm × .06 mm. Vesicula seminalis .1 mm × .065 mm Pars prostatica 135 mm.

\* Vide Proc. Ind. Acad. Sci., 1936, 4, No. 2, Sec. B., 92-93.

long. Male genital opening lies at about 09 mm from the ventral sucker. Ovary 105 mm  $\times$  06 mm. Eggs numerous with thick shell and without filaments, measure 017 mm  $\times$  006 mm. Vitelline glands in groups of 5 or 6 just behind testes.

*Host*—*Gallinago gallinula* (Bursa fabricii)

*Locality*—Lucknow

*Remarks on the family Microphallidae*—The subfamily Microphallinae Ward (1901) was raised to the status of a family Microphallidae by Travassos (1920). This family shows distinctive differences from the family Heterophyidae in the copulatory apparatus, the absence of a receptaculum seminis and the nature of the genital pore. It has, therefore, been rightly excluded from the latter family and kept as a separate family.

The type genus of the subfamily Microphallinae is *Microphallus* which is characterised by the absence of a cirrus sac. The genus *Maritrema* has also been included under the same subfamily although it shows a well-developed cirrus sac. The presence of a cirrus sac alone, as indicated earlier (Lal, 1937), is sufficient for the exclusion of the genus *Maritrema* from this subfamily. The writer, therefore, considers it desirable to retain the subfamily Microphallinae for only those forms in which a cirrus sac is absent, and to create a new subfamily Maritreminae for the reception of other forms which possess a cirrus sac.

The family Microphallidae is divided into two sub-families thus—

- 1 Subfamily Microphallinae
- 2 Subfamily Maritreminae N Subfam

*Diagnosis of the subfamily Microphallinae*.—

Microphallidae without a cirrus sac. Vesicula seminalis and pars prostatica lying free in the parenchyma. Vitellaria in groups of 5–7 follicles on each side behind the testes.

Type genus—*Microphallus*

*Diagnosis of the subfamily Maritreminae N Subfam*

Microphallidae with a cirrus sac. Vesicula seminalis and pars prostatica inside the cirrus sac. Vitellaria in the form of a band.

Type genus—*Maritrema*

## Family Cephalogonimidae Nicoll, 1914

Nicoll (1914) erected the family Cephalogonimidae for the reception of the subfamily Cephalogoniminae Looss, 1899 Pande (1932) and Bhalerao (1936) think that the family should be brought back to the subfamily status and should be included in Plagiorchidae In support of this view, Bhalerao (1936) has pointed out that Nicoll (1935) has himself included it in Plagiorchidae He has also tried to show that the position of the genital pore in some genera of Plagiorchidae, viz., *Renifer*, *Ochetosoma* and *Lechriorchis* is lateral to pharynx and forms a near approach to the condition met with in Cephalogonimidae and further that there is a similarity in the nature of the excretory bladder in the two cases The writer, however, does not agree with Bhalerao in his contention The mere fact, that the original author does not mention Cephalogonimidae as a distinct family at a later stage, should not be enough to prove the non-existence of the family The condition of the genital pore and cirrus sac as also some other characters are very distinctive in Cephalogonimidae and it would be more appropriate to regard it as a distinct family Some of the genera of Plagiorchidae mentioned by Bhalerao should be simply regarded as connecting links showing a possible transition from one family to the other This does not, however, invalidate the existence of two distinct families, Cephalogonimidae and Plagiorchidae

## Diagnosis of the family Cephalogonimidae Nicoll, 1914 —

Skin spiny Prepharynx and pharynx present, oesophagus variable, crura  $\frac{1}{2}$  to more than  $\frac{3}{4}$ th length of the body Excretory vesicle Y-shaped, sometimes with a caudal vesicle The median stem of the 'Y' is shorter than the branches Genital pore marginal, dorsal or anterior to the oral sucker The cirrus sac long and sinuous or saccular, extending to or beyond the intestinal bifurcation Testes behind acetabulum and ovary Ovary close to the acetabulum and on the right side of the median line of the body Receptaculum seminis and Laurer's canal present Uterine coils in ascending and descending rami, chiefly in posterior region behind the testes Eggs thick-walled and numerous

Type genus—*Cephalogonimus*

The family is represented by the genus *Prosthogonimus* among birds in India

Genus *Prosthogonimus* Lühe, 1899

*Diagnosis* — Body small or medium in size, flattened, with the maximum breadth behind the middle Skin spiny Prepharynx short Oesophagus

of medium size Excretory bladder Y-shaped Testes symmetrical, behind ovary and acetabulum Ovary close to acetabulum Cirrus sac long, slender and sinuous with convoluted vesicula seminalis Genital pore marginal at the level of the oral sucker Receptaculum seminis and Laurer's canal present Vitellaria extra-cæcal Uterus in coils in posterior part of the body, chiefly behind the testes Eggs numerous

*Remarks on the genus Prosthogonimus* —The genus *Prosthogonimus* was transferred to the family Plagiorchidæ by Poche (1925) Fuhrmann (1928) and Sprehn (1932) also keep it under Plagiorchidæ Sinha (1932) has discussed at length the differences between the genus *Prosthogonimus* and the family Plagiorchidæ and removed the genus to the family Cephalogonimidae to which view the writer fully subscribes

*Prosthogonimus cuneatus* (Rudolphi, 1809) Braun, 1901

A single specimen of this parasite was obtained by Dr G S Thapar from the bursa fabricii of the common mynah, *Acridotheres tristis*

The specimen measures 4 95 mm × 2 375 mm The oral sucker is terminal and measures 2 mm × 2.5 mm The pharynx measures 1.75 mm × 1 mm This is followed by a long oesophagus 3 mm in size which bifurcates at its posterior end into the two intestinal cæca The ventral sucker is well developed and lies at a distance of 1.8 mm from the anterior end It has a circular shape and measures 6 mm in diameter

The testes lie at the same level behind the ovary and the ventral sucker They are 6 mm apart from each other and oval in outline They measure 7.5 mm × 4 mm The cirrus sac is a slender and sinuous structure, containing coiled vesicula seminalis It opens at the lateral margin of the body by the side of the oral sucker

The ovary is greatly lobed and lies in between the right testis and the ventral sucker It measures 6 mm × 4 mm The receptaculum seminis is a more or less spherical body lying just behind the ovary on the inner border of the testes The ootype occupies a small area just behind the ventral sucker

The vitellaria are confined almost to the middle third of the body. They are extra-cæcal, and consist of a large number of distinct small and rounded follicles

The uterus fills up the entire space behind the testes It has both ascending and descending convolutions which pass in between the two

testes In front of the ventral sucker the uterus runs more or less straight to form the metraterm which runs along the cirrus sac and opens at the genital pore The eggs are numerous but small and measure 0.2 mm x .01 mm

### *Family Echinostomidae* Looss, 1902

The family Echinostomidae was erected by Looss (1902) for the reception of his subfamily Echinostominae and some other genera Dietz (1909) described a large number of forms from avian hosts. Odhner (1910) attempted to classify the family into three subfamilies, Echinostominae, Himasthlinae and Echinochasminae A large number of genera have been described under the family which are not included in any of the existing subfamilies Recently the writer (Lal, 1936) erected a new subfamily Parorchinæ for the reception of the genus *Parorchis* The family Echinostomidae has the following diagnosis —

Body more or less elongated, small or very large, usually much flattened anteriorly, less so, or even cylindrical posteriorly Oral sucker small and weak, surrounded dorsally and laterally, but not ventrally, by a collar-like fold, bearing one or two rows of spines, which are continued laterally to ventral corners, the corner spines sometimes large or specialized, acetabulum large and powerful, usually pre-equatorial and sometimes near oral sucker Cuticle usually spinose, specially anteriorly Excretory vesicle Y-shaped, with lateral twig-like branches Pharynx and oesophagus present, intestinal cæca extend to posterior end of body Genital aperture pre-acetabular, genital sinus present or absent Cirrus pouch usually present Testes post-equatorial, tandem or connubial in position Ovary pre-testicular, usually to right of median line, Laurer's canal present Receptaculum seminis present or absent Vitellaria lateral, rarely extending anterior to acetabulum, sometimes confined to middle and consist of distinct and big follicles Uterus in transverse coils, rarely extending beyond intercæcal field Parasites of intestines or bile ducts of vertebrates

The family is divided into four subfamilies —

- 1 Echinostominae Looss, 1899—Type subfamily
- 2 Himasthlinæ Odhner, 1910
- 3 Echinochasminæ Odhner, 1910
- 4 Parorchinæ Lal, 1936

### *Subfamily Echinostominae* Looss, 1899

*Diagnosis* —Echinostomidae, cirrus sac generally extends up to the centre of the ventral sucker and is never pushed behind Cirrus long.

generally not covered with spines and when contracted it appears to be coiled Seminal vesicle coiled and undivided Collar spines in one or two rows, continuous on the dorsal side

Type genus—*Echinostoma*.

*Echinostoma revolutum* Looss, 1899

*Host*—*Anas pectorrhyncha* (Intestine)

*Locality*—Rangoon

*Remarks*—Gogate (1934) obtained this species from the duck, *Anas pectorrhyncha* but gives no description or diagram. He mentions that the only feature in which his form differs from the description of Lühe (1909) is the size. The biggest of them is only a little longer than the smallest mentioned in the description. The writer has no specimens of this species in his possession and cannot add to the description. A summary of Lühe's description is, however, given below —

" Body 10-21 mm long Mouth sucker 25—50 mm Pharynx 21—35 mm Ventral sucker 67-1 69 mm Cuticle spiny Collar spines 37 There are 27 'Randstacheln' and 5 'Eckstacheln' on either side Sometimes spines 35 in number Testes of very variable shape, in post equatorial body Vitellaria extend up to the level of the acetabulum from the posterior end They do not meet in the middle in the region of uterus or testes Eggs .097—126 mm × .059—.071 mm "

*Echinostomum govindum* Moghe, 1932

Body 4.6—4.94 mm × .92 mm Cuticle with spines numerous anteriorly but absent in the post-testicular region Oral sucker 149 mm × 133 mm, surrounded by reniform collar of 32 spines There are 4 spines on each side placed close together Short prepharynx Muscular pharynx 22 mm × 36 mm followed by long oesophagus Intestinal cæca run up to .14 mm from posterior end Ventral sucker sub-globular lies about .96 mm from anterior end and measures .6 mm in diameter Testes, ovoid, post-ovarial, .4 mm × 24 mm in size, lie one behind the other Cirrus sac ovoid, lies between intestinal bifurcation and anterior border of ventral sucker. It contains transversely elongated vesicula seminalis surrounded by prostatic glands Genital pore behind the intestinal bifurcation Ovary pre-testicular, .12 mm in diameter. Shell-gland lies between ovary and anterior testis Uterus runs up to ventral sucker Vagina runs dorsal to ventral sucker and cirrus sac Vitellaria, rounded follicles, extend from posterior end of intestinal cæca to anterior level of ventral sucker Eggs .047 mm × .028 mm

*Host*—*Philomachus pugnax* (Rectal cæca)

*Locality*—Nagpur

*Echinostoma chasma* n. sp

Two immature individuals of this species were obtained from the small intestine of the garganey, *Querquedula circia* at Amausi. The most remarkable feature of this form is the excretory bladder which is greatly

sinuous and showed peculiar periodical expansions and contractions of its stem

The body which has spiny cuticle is elongated with a broad posterior end and measures  $2\frac{5}{8}$  mm  $\times$  64 mm. The head with collar of spines is marked off clearly from the rest of the body. The collar spines are 34 in number and are arranged in one regular row without break on the dorsal side. The dorsal spines measure .075 mm and the lateral and marginals .05 mm in length.

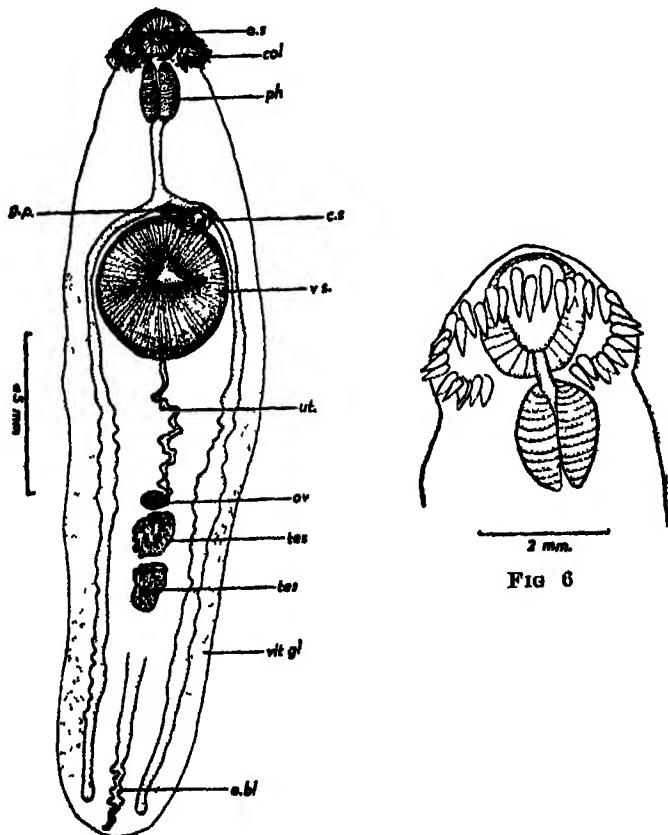


FIG. 5

FIG. 6

FIG. 5. *Echinostoma chasma* n. sp., entire worm—ventral view. Body spines not shown.

FIG. 6. *Echinostoma chasma*, head collar showing spines (Sketched from glycerine mount)

The oral sucker is .15 mm in diameter. There is a small prepharynx, and a muscular pharynx measuring 175 mm  $\times$  125 mm. The oesophagus is 25 mm long and bifurcates at its posterior end into two intestinal cæca.

which are wide and have greatly crenated margins and run close by the side of the acetabulum up to the posterior end of the animal

The ventral sucker is 45 mm  $\times$  .41 mm and lies at a distance of .65 mm from the anterior end

The testes are ovoid bodies, the anterior measures 13 mm  $\times$  15 mm and the posterior 11 mm  $\times$  15 mm. The cirrus sac, which partially overlaps the ventral sucker on the left side, contains an incompletely bilobed vesicula seminalis. The cirrus is fairly long and opens at the genital pore just in front of the acetabulum and behind the intestinal bifurcation

The ovary is oval and pretesticular and measures 85 mm  $\times$  55 mm. The shell-gland, ootype, etc., could not be observed. The uterus runs in more or less sinuous but straight course dorsal to ventral sucker in the median line and opens at the genital pore. No eggs are present in the uterus.

The vitellaria are not fully developed and consist of small follicles of diffuse nature, extending from the posterior end up to the level of the middle of the ventral sucker.

**Remarks** —The form described above comes under the genus *Echinostoma* owing to its having a collar of spines uninterrupted on the dorsal side, cirrus sac anterior to the ventral sucker and a non-spiny cirrus. But the form is peculiar in possessing an incompletely bilobed seminal vesicle, a feature in which it differs from all the existing species of the genus and resembles the subfamily *Echinochasminae*. Although greater details of anatomy are not known owing to immature state of the specimens, the writer feels inclined to regard it as a new species of the genus *Echinostoma* showing a transitional stage in the lobation of the vesicula seminalis.

#### *Subfamily Himasthlinæ Odhner, 1910*

No representative of this subfamily has been reported so far from avian hosts in India.

#### *Subfamily Echinochasminae Odhner, 1910*

*Echinostomidae* —Cirrus sac is pear-shaped and does not reach even up to the centre of the ventral sucker. Seminal vesicle is not coiled and is sharply divided into two parts. Pars prostatica present. Ductus ejaculatorius is extremely short. Collar spines generally in one row but some show arrangement in a double row. They are discontinuous on the dorsal side and 20–26 in number.

Type genus—*Echinochasmus*

*Echinochasmus megavitellosus n. sp.*

A large number of these parasites were obtained from the intestine of the paddy bird, *Ardeola grayi*. The worms exhibited slow movements of their body when liberated in normal salt solution.

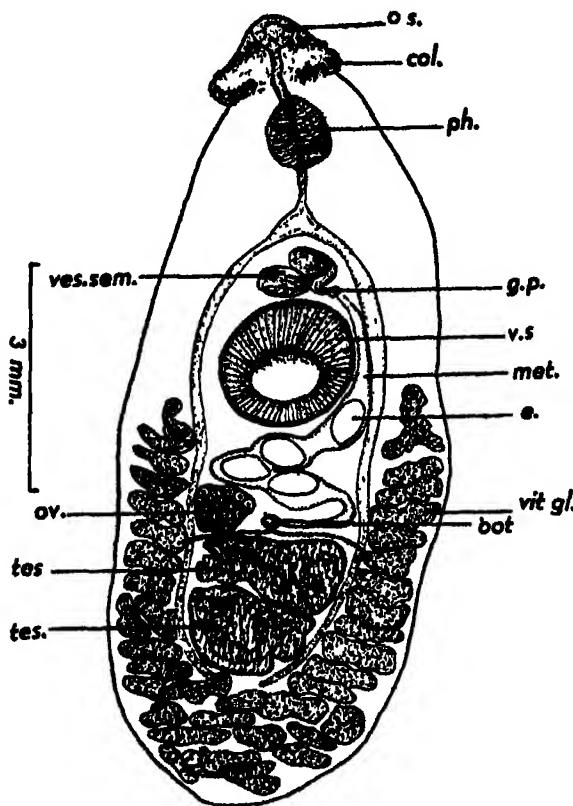


FIG. 7

FIG. 7. *Echinochasmus megavitellosus n. sp.*, entire worm—ventral view. Body spines not shown

The body is elongated oval and measures  $1\ 05 \text{ mm} \times 45 \text{ mm}$ . The cuticle bears spines. The anterior end has a prominent head which bears a collar of spines. The collar spines numbering 24, are arranged in one single row, leaving a little space on the dorsal side. They are arranged in two groups of 12 spines each and are of uniform size measuring .025 mm. long

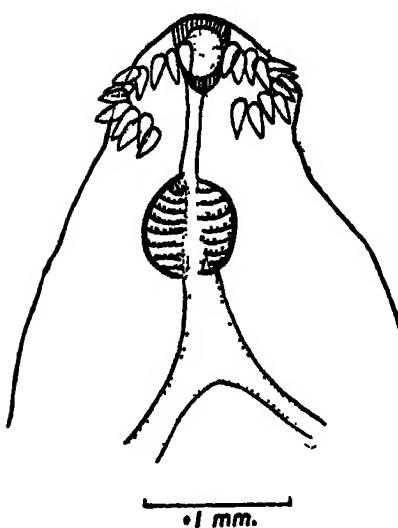


FIG. 8

FIG. 8 *Echinochasmus megavittellus* n. sp.—Head collar showing spines (Sketched from glycerine mount)

The oral sucker is sub-ventral and measures  $06 \text{ mm} \times .05 \text{ mm}$ . The mouth leads into a thin, prepharynx  $.075 \text{ mm}$  in size. This is followed by a muscular pharynx measuring  $09 \text{ mm} \times 1 \text{ mm}$ . The oesophagus is short and bifurcates at its posterior end into the two intestinal cæca which run up to the posterior end of the testes. Their terminal ends are curved inwards and come near each other but do not meet.

The ventral sucker is strong and powerful and measures  $18 \text{ mm} \times 17 \text{ mm}$ . It lies at a distance of  $38 \text{ mm}$  from the anterior end and  $09 \text{ mm}$  behind the intestinal bifurcation.

The testes lie very close to each other in the posterior third of the body and are intercæcal in position. The anterior testis measures  $2 \text{ mm} \times 11 \text{ mm}$  and the posterior  $17 \text{ mm} \times 112 \text{ mm}$ . The vesicula seminalis lies in front of the ventral sucker and is a bilobed body of  $1 \text{ mm}$  length. It ends in a small ductus ejaculatorius which is surrounded by prostate gland cells. The vesicula seminalis, ductus ejaculatorius, a short cirrus and prostate gland cells are all enclosed in a thin-walled cirrus sac which lies in a transverse position just in front of the ventral sucker.

The ovary which lies on the right side of the median line in front of the two testes is an ovoid structure and measures  $.08 \text{ mm} \times .07 \text{ mm}$ .

The ootype lies in the median plane a little to the left of the ovary in front of the anterior testis and is surrounded by small unicellular shell-glands. There is no receptaculum seminis in these forms. The uterus arises from the left side of the ootype. It is a short tube, thick in the middle, and contains very few eggs. It is confined between the ootype and the ventral sucker and ends in a thick-walled metraterm which runs along the left border of the ventral sucker and opens at the genital pore which lies at a distance of 0.2 mm in front of the ventral sucker. The eggs are fairly large and thick-shelled and measure 0.7 mm x 0.5 mm.

The vitellaria consist of very large and compact follicles lying in the posterior half of the body behind the ventral sucker. They are extra-cæcal and meet together behind the testes filling up all the post-testicular space. The two transverse vitelline ducts run just in front of the anterior testis and open together into the ootype.

**Remarks** —The present form differs from all the described species of the genus *Echinocasmus* except *E. mordax*, besides several other features, in the position of its cirrus sac which is transversely placed and is slightly ahead of the ventral sucker. From *E. mordax* it differs in possessing two extra collar spines, ratio of oral to ventral sucker, in having bigger testes and smaller ovary and in having big massive extra-cæcal vitellaria. The present form, therefore, appears to be new to science and because of its large vitellaria is named *Echinocasmus megavitellus*, n. sp.

#### *Echinocasmus removarus* n. sp (Figs 9 & 10)

Several specimens of this Trematode were recovered from the intestine of the common house crow, *Corvus Splendens*. The worms are more or less oval in shape and measure 1.17 mm x 4.25 mm. The cuticle bears minute spines which extend up to the anterior testis. The head is very prominent and possesses a well-developed collar beset with spines. The collar spines are 24 in number and are arranged in two groups of 12 spines each leaving a short space on the dorsal side in the region of the oral sucker. They show a slight variation in size increasing in length towards the dorsal surface and form a single row except for 4 pairs of spines towards the pharynx which show an alternating arrangement.

The oral sucker is 1 mm x 0.95 mm. The prepharynx is extremely small. The pharynx measures 0.9 mm x 0.6 mm and leads into an oesophagus of moderate size which bifurcates into the two intestinal cæca at its posterior end.

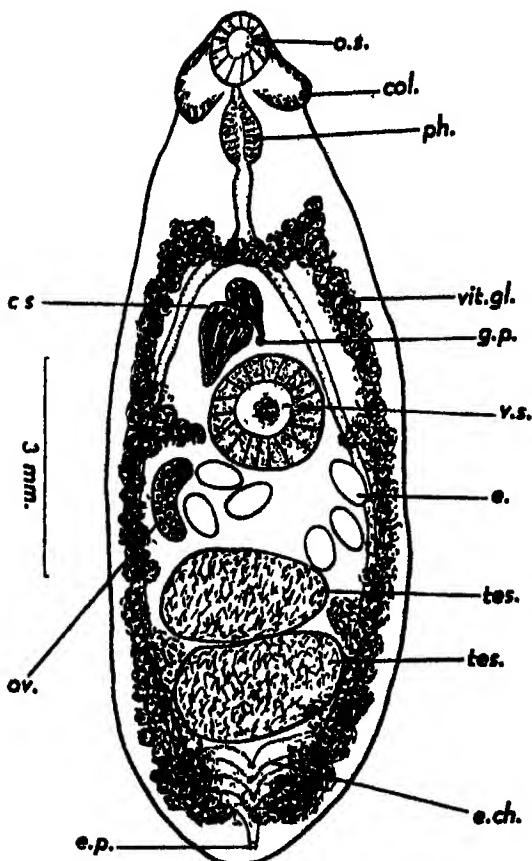


FIG. 9

FIG. 9 *Echinochaetus removarus* n. sp., entire worm—ventral view (Body spines not shown)

FIG. 10 *Echinochaetus removarus* n. sp. Head collar showing spines. (Sketched from glycerine mount)

The ventral sucker, larger than the oral, is circular in outline and measures 16 mm in diameter. It lies at a distance of .46 mm from the anterior end and 13 mm behind the intestinal bifurcation

The excretory bladder is peculiar inasmuch as it shows five tubular chambers opening one after the other into the bladder. These are just the lateral branches of the stem of the bladder which have become dilated at their proximal ends. This gives a chambered appearance to the excretory bladder. The excretory pore is dorsal and sub-terminal

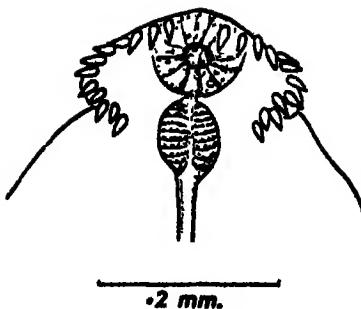


FIG. 10

The testes, two in number, much broader than long, are contiguous and occupy the posterior third of the body. The anterior testis measures .25 mm x 14 mm and the posterior 26 mm x 14.5 mm.

The vesicula seminalis is distinctly bilobed and lies on the right side of the median line immediately in front of the ventral sucker. The cirrus is short and is enclosed in a cirrus sac which also encloses the vesicula seminalis and prostate gland cells. The genital pore lies at a distance of 0.16 mm in front of the acetabulum in the middle line.

The ovary is pre-testicular, kidney-shaped and dextral in position. It measures 11 mm x 0.5 mm. The ootype complex lies on the left of the ovary just in front of the anterior testis. The uterus is short and contains a few eggs which are thick-shelled, large and measure 0.75 mm x 0.45 mm.

The vitellaria which consist of small rounded follicles extend from the posterior end of the body right up to the level of the pharynx. They meet both anteriorly and posteriorly and form a wreath of follicles across the body.

**Remarks** —The present form differs from all the species of the genus except *E. bagulai* in possessing a chambered arrangement of the excretory bladder. But it differs from *E. bagulai* in the greater anterior extension of the vitellaria and shape of the ovary and testes. In its general external appearance it stands nearest to *E. corvus* from which it differs in the position of the cirrus sac and possessing a distinctly chambered excretory bladder.

It is, therefore, regarded as a new species which is designated *E. removarus* because of its possessing a kidney-shaped ovary.

#### *Echinocchasmus corvus* Bhalerao, 1926

Body 1.06-1.08 mm. x .465-49 mm. Collar kidney-shaped with 24 spines, disposed in one row, broken dorsally by a short space 3 + 3 'Eckstacheln' and 9 + 9 'Randstacheln'. Oral sucker .070-.080 mm in diameter. Ventral sucker measures .13-.14 mm in diameter. Prepharynx present, short .027 mm in length. Pharynx .058 mm. Intestinal ceca simple, extend to the posterior end of the body. Testes, one behind the other, separated by a broad band of vitellaria from the posterior end. Anterior testis, transversely oval, entire margin and measures 26 mm x 15 mm. Posterior testis somewhat round but flattened anteriorly, and measures 23 mm x .175 mm. Cirrus sac lies dorsal to ventral sucker, in the median line, and extends posteriorly almost to the hind margin of ventral sucker. Genital pore, pre-acetabular and behind intestinal bifurcation. Vesicula seminalis well developed. Pars prostatica and ductus ejaculatorius very small. Ovary immediately anterior to testes, dextral, oval, measures 1-.18 mm x .08-.105 mm. Receptaculum seminis round, present on its inner side. Laurer's canal present, shell-gland in front of anterior testis. Uterus small, containing very few eggs, between anterior testis and ventral sucker.

Eggs oval, operculated, with brown shell, and measure .07-.085 mm  $\times$  .045-.06 mm  
 Vitellaria consist of large rounded follicles, situated dorsally along the side of body  
 Vitellaria meet centrally in front of ventral sucker and posteriorly behind the testis  
 They do not extend up to pharynx.

*Host* — *Corvus insolens* (Intestine)

*Locality* — Rangoon

*Echinocasmus ruficapensis* Verma, 1935

Body length 2.5 — 3.5 mm, maximum breadth, in front of acetabulum, 0.4—0.6 mm Oral sucker spherical 0.16 mm or oval 0.15 mm  $\times$  0.1 mm Collar large, transversely elongated, reniform or triangular, 0.30-0.45 mm  $\times$  0.5-0.65 mm, collar spines 24, dorsally interrupted in one regular row on each side, ventral-most of each side smaller, others nearly equal Prepharynx 0.1-0.2 mm, pharynx oval, 0.15 mm  $\times$  0.17 mm., oesophagus long, 0.25-0.5 mm Ventral sucker sub-globular, 0.35 mm in diameter, at one-third the body length from anterior end Ovary small, oval, along mid-transverse line or slightly ahead of it, testes median, close behind one another, in posterior half of body, margin smooth, anterior subquadrate or ovo-spherical, broader than long 0.18-0.22 mm  $\times$  0.19-0.35 mm; posterior ovo-spherical or sub-triangular 0.18-0.25 mm  $\times$  0.18-0.2 mm Ova 0.07-0.08 mm  $\times$  0.089-0.052 mm

*Host* — *Podiceps ruficollis*

*Locality* — Allahabad

*Echinocasmus bagular* Verma, 1935

Length 1.0 mm to 1.75 mm, maximum width, about middle of body, 0.25 mm to 0.5 mm Oral sucker 0.07 mm in diameter Collar reniform with 24 spines, interrupted dorsally, in two rows, alternating with one another, spines of outer row 0.025-0.035 mm long, of inner row 0.021 - 0.027 mm long Prepharynx about 0.05 mm long, pharynx 0.042-0.59 mm in diameter, oesophagus 2½ to 3 times as long as pharynx Ventral sucker 0.2 mm in diameter Ovary and testes in posterior half of body, ovary rounded, 0.05 mm in diameter, to right of median line, testes median close behind one another; transversely elongated, variable in form and outline, anterior testis usually somewhat smaller in dimensions than the posterior Eggs large, 7 to 15 or more and measure 0.067-0.0758 mm  $\times$  0.050-0.0588 mm

*Hosts* — *Ardeola grayi* & *Nycticorax nycticorax* (Small intestine)

*Locality* — Allahabad & Nagpur

*Stephanoprora fusca* n. sp

Two specimens of this trematode were obtained from the small intestine of the spotted red-shank, *Totanus fuscus* The worms are elongated and cylindrical in shape and measure 4.775 mm  $\times$  45 mm, the greatest width being a little behind the posterior testis The head is marked off from the rest of the body and bears a collar of 22 spines The spines are arranged in two groups of 11 each, leaving a short space on the dorsal side in the region

of the oral sucker. The spines are of uniform size, measuring 0.5 mm x 0.2 mm and are arranged in one row except for four pairs of spines towards the pharynx which show an arrangement in double row.

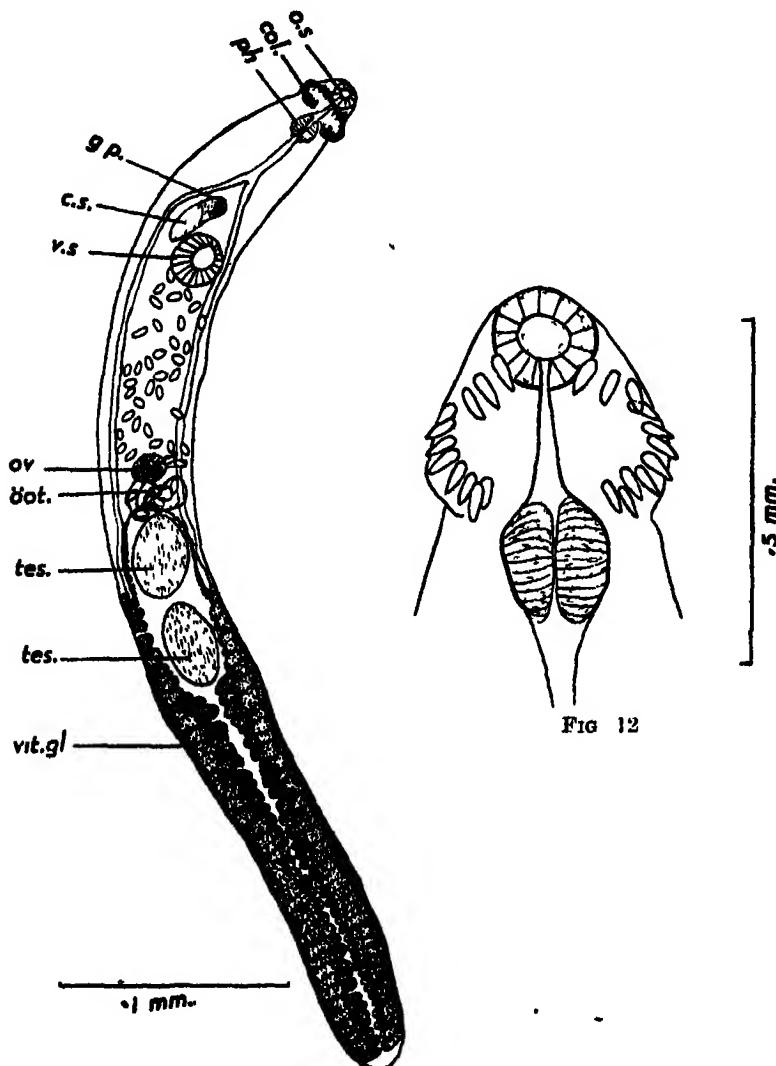


FIG. 11

FIG. 11. *Stephanoprorra fusca* n. sp., entire worm—ventral view.

FIG. 12. *Stephanoprorra fusca*—head collar showing spines (Sketched from glycerine mount.)

The oral sucker is sub-ventral and measures .1 mm in diameter. There is a small prepharynx measuring .15 mm and this leads into a muscular pharynx which measures 125 mm  $\times$  .1 mm This is followed by an oesophagus 275 mm long which bifurcates at its posterior end into the two intestinal cæca which run up to the posterior end of the body

The ventral sucker is strong and muscular and measures 25 mm in diameter It lies at a distance of 9 mm from the anterior end and 3 mm behind the intestinal bifurcation

The testes are oval with entire margin and lie at about the middle of the body The anterior testis measures 375 mm  $\times$  25 mm and the posterior 4 mm  $\times$  22 mm The vesicula seminalis is bilobed and lies on the right side of the median line It is enclosed in a thin-walled cirrus sac which also contains a small cirrus surrounded by prostate gland cells. The cirrus sac measures 3 mm in length and bears the genital aperture at its anterior tip

The ovary is situated at a distance of 75 mm. behind the ventral sucker in front of the two testes in the median line It is oval in shape and measures 15 mm  $\times$  11 mm The ootype complex lies between the ovary and the anterior testis There are a large number of small unicellular shell-glands present around the ootype The uterus arises from the left side of the ootype, curves behind and after forming a loop runs dorsal to ovary towards the anterior end There are a large number of eggs present in the uterus which measure 05 mm  $\times$  025 mm

The vitellaria consist of elliptical follicles and extend in between the testes to the posterior end The follicles of the two sides approach each other but do not meet in the middle The two vitelline ducts run parallel to the body in a longitudinal direction to open into a very small yolk reservoir A small and narrow duct from the yolk reservoir leads into the ootype

**Remarks.**—The form described above differs from all the existing species of the genus *Stephanoprora* It differs from *S. polycestus* and *S. reynoldsi* in the absence of a receptaculum seminis From *S. pseudoechinatus*, *S. ornata* and *S. spinosa* it differs in the position of the cirrus sac It stands nearest, however, to *S. merulæ*, *S. denticulatus* and *S. conciliatus*. But it differs from *S. merulæ* in having smaller eggs, well convoluted uterus and in the absence of a receptaculum seminis uterini. From *S. denticulatus* it differs in possessing smaller eggs and in not having its cirrus sac contiguous with the ventral sucker It differs from *S. conciliatus* in having

a dextral position of the cirrus sac, smaller eggs, longer prepharynx and non-contiguous testes It is therefore, a new species for which the name *Stephanoprora fusca* n. sp is proposed

*Stephanoprora reynoldi* Bhalerao, 1926

Body elongated, cuticle covered with spines up to the posterior margin of anterior testis. Collar kidney-shaped with 22 spines in one row and broken dorsally 2 'Eckstacheln' and 9 'Randstacheln' on each side Oral sucker 21 mm x 88 mm Prepharynx short Testes with entire margin one behind the other, in the middle of body Anterior testis .39 mm x 33 mm, posterior .50 mm x .33 mm. Cirrus sac situated sinistral to ventral sucker and extends from the intestinal fork to the posterior end of ventral sucker, pear-shaped and contains two-lobed vesicula seminalis Pars prostatica and ductus ejaculatorius small Ovary, anterior to testes, oval, slightly dextral and measures .15 mm x 115 mm Receptaculum seminis post-ovarial, and shell-gland behind it Laurer's canal present Uterus, with few ova, between anterior testis and ventral sucker Eggs measure 058- 0805 mm x 031- 049 mm Vitellaria consist of large follicles Yolk reservoir present Vitellaria extend from the centre of the anterior testis to the posterior end and run lateral to the body, approaching each other closely at the posterior end Excretory pore terminal.

*Host*—*Corvus insolens* (Intestine)

*Locality*—Rangoon

*Subfamily Parorchinæ Lal, 1936\**

*Genus Parorchis Nicoll, 1907*

This genus is of rare occurrence and is recorded for the first time in India and the species *Parorchis snipis* Lal, 1936, forms the third valid species of the genus

*Parorchis snipis* Lal, 1936\*

Body baset with spines for the anterior 2/3rd part; 2.58 mm x 1.11 mm Head inconspicuously marked, ridge-like collar, with single row of minute spines Four pairs of spines at the lateral margin of collar larger, .025 mm long Oral sucker .24 mm x 27 mm Ventral sucker 58 mm x 55 mm Prepharynx .07 mm Pharynx .12 mm x 18 mm Oesophagus 19 mm long Excretory bladder 26 mm x .3 mm Right testis .35 mm x 27 mm Left testis 36 mm x 225 mm Vesicula seminalis behind the ventral sucker 2 mm x 13 mm Cirrus sac .09 mm long Ovary .186 mm x 14 mm Receptaculum seminis behind ovary .035 mm x .082 mm Shell-gland post-ovarial Male and female openings lie together in a genital atrium behind intestinal bifurcation Eggs in a single row, show segmentation, and measure .05- .06 mm x .025 mm Vitelline glands, about a dozen follicles on each side, partly extra-cæcal and partly intercæcal.

*Host*.—*Totanus hypoleucus* (Cloaca)

*Locality*.—Lucknow.

The author also discussed the systematic position of the genus *Parorchis* and came to the conclusion that this genus should be placed in a separate subfamily *Parorchinæ* Lal, 1936, in the family *Echinostomidæ*. In the same communication\* evolution of *Echinostomes* was discussed and a polyphyletic origin of *Echinostomidæ* was suggested.

### *Isolated Genera of the Family Echinostomidæ*

The genera *Paryphostomum* and *Petasiger* are not included in any of the existing subfamilies of *Echinostomidæ*. The writer is not in possession of material of these forms and cannot definitely express his opinion. But on looking up the available literature, he finds that both these genera should be included in the subfamily *Echiphystominæ*, because of the arrangement of collar spines in an uninterrupted row and non-extension of its cirrus sac behind the ventral sucker.

### *Paryphostomum testitritifolium* Gogate, 1934

Body elongated 3.5–5 mm., armed with spines in front of ventral sucker. Maximum width in the region of testes .555–.952 mm. Head collar strongly developed single row, 27 spines, unbroken dorsally. Ventrally collar spines gathered into two 'end groups' of 4 spines each. Oral sucker sub-terminal, measures .115 mm. × .128 mm. Prepharynx small, .027 mm. Pharynx globular .135 mm. × .093 mm. Oesophagus 464 mm long. Intestinal cæca run to posterior end of body. Ventral sucker .547 mm. × .539 mm enclosing a spacious cup-shaped cavity. Genital pore in between ventral sucker and intestinal bifurcation, median. Testes, branched, trifoliate, two antero-lateral and one postero-median branches lying one behind the other, posterior larger than anterior. Cirrus pouch .197 mm. × .0945 mm., dorsal and oblique to ventral sucker. Ovary globular, .17 mm. × .185 mm., pre-testicular. Shell-gland in between ovary and anterior testis. Receptaculum seminis, posterior to ovary. Vitellaria extend between ventral sucker and posterior end of body, filling the post-testicular portion with loosely packed follicles. Uterus, short not much coiled, pre-testicular, intercæcal. Vagina is dorsal to ventral sucker. Ova, numerous, small .0771 mm. × .0409 mm.

*Host*—*Dendrocygna javanica* (Intestine).

*Locality*—Rangoon.

### *Petasiger minutissimus* Gogate, 1934

Body small, elongated .948–1.338 mm. Well-developed head collar with 23 spines, of which 17 are arranged in a single dorsally uninterrupted row, measuring .0308–.0618 mm. × .01–.0171 mm. Remaining 6 spines, in two ventral 'end groups' each with 3 spines, measuring .0552–.073 mm. × .015–.0225 mm. Maximum width

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\* Vide Proc. Ind. Acad. Sci., 1936, 4, No. 1, Sec. B, 27–35.

behind ventral sucker .201-.349 mm Body anterior to ventral sucker covered with spines. Oral sucker 045-.053 mm Prepharynx .05-.06 mm Pharynx globular .0495-.05 mm. Oesophagus thin .3-.33 mm Intestinal caecal ends hidden in the vitellaria Ventral sucker .177-.195 mm x .198-.226 mm. Genital pore, ventral to intestinal bifurcation Testes oval, overlapping, with long axes at right angles Cirrus pouch 113 mm x .121 mm dorsal to ventral sucker and half portion extending between it and the intestinal bifurcation Ovary ovoid, .0644-.064 mm x .066 mm close to ventral sucker, lateral Receptaculum seminis and shell-gland obscured by vitelline follicles Vitelline follicles behind posterior margin of ventral sucker to posterior end of body and filling loosely the post-testicular region Uterus, pre-testicular, short Ova, few large 0592-.093 mm x .0368-.048 mm

*Host* — *Dendrocygna javanica* (Intestine)

*Locality* — Rangoon

Key for the identification of the Avian Genera and Species of the family Echinostomatidae reported from India

1	Testes connubial .	<i>Parorchis snipis</i>
	Testes tandem ..	2
2	Spines on collar broken on the dorsal side .	3
	Spines on collar uninterrupted on dorsal side	4
3.	Collar spines 24	<i>Echinochasmus</i> (see 6)
	Collar spines 22 .	<i>Stephanoprora</i> (see 10)
4	Seminal vesicle undivided .	5
	Seminal vesicle incompletely bilobed	<i>Echinostoma chasma</i>
5.	Collar spines 27 .. .	<i>Paryphostomum testitrifolium</i>
	Collar spines 23 .. .	<i>Petasiger minutissimus</i>
	Collar spines 32 . .	<i>Echinostomum govindum</i>
	Collar spines 37 . .	<i>Echinostoma revolutum.</i>
6	Excretory bladder with chambered diverticula .. .	7
	Excretory bladder without chambered diverticula . .	8
7.	Vitellaria extend preacetabular .	<i>Echinochasmus reniovarus.</i>
	Vitellaria behind acetabulum ..	<i>Echinochasmus bagular</i>
8.	Vitellaria meet in the pre-acetabular region .. .	<i>Echinochasmus corvus.</i>
	Vitellaria behind acetabulum ..	9

- |    |   |                                    |
|----|---|------------------------------------|
| 9  | Cirrus sac, transverse, ahead of ventral sucker . . . . . | <i>Echinochasmus megavittellus</i> |
|    | Cirrus sac, vertical, touching ventral sucker . . . . .   | <i>Echinochasmus ruficapensis</i>  |
| 10 | Cirrus sac dextral . . . . .                              | <i>Stephanoprora fusca</i>         |
|    | Cirrus sac sinistral . . . . .                            | <i>Stephanoprora reynoldi</i>      |

*Family Psilostomidae* Odhner, 1913

Odhner (1913) raised the subfamily *Psilostominae* Lühe (1909) to the status of the family *Psilostomidae* and described several new genera under it. Travassos (1921) added the genus *Lyperorchis* and Bhalerao (1931) described another genus *Testifrondosa*† from the intestine of pig. Thapar and Lal (1935) described from King-fisher the genus *Psilorchis*, the only Avian genus of Trematode recorded from India under the family Lal (1938) described the second species, *Psilorchis aigainis*, of the genus from *Nettion crecca*.

*Family Diagnosis*—Worms with flattened leaf-like body of variable length. Head indistinct without any collar. The internal structure is comparable to that of the family *Echinostomidae*. Skin smooth or sometimes covered with scale-like or simple spines. Pharynx strongly developed. Intestinal bifurcation in front of the ventral sucker. Intestinal cæca reach almost up to the posterior end of the animal. Excretory bladder Y-shaped. The two limbs of the bladder join each other in the region of the ventral sucker to form a big unpaired sinus. Ovary is anterior to both the testes. The disposition of the genital apparatus is on the same plan as that in *Echinostomidae*. Vitellaria consist of distinct follicles and present on the lateral sides of the body ventral to intestinal cæca. They do not always meet together in the middle line posteriorly. Eggs similar to those of the *Echinostomes*, about 088–125 mm long. Parasitic in the intestine of birds and mammals.

*Genus Psilorchis* Thapar and Lal, 1935

*Psilostomidae* with leaf-like body. Ventral sucker much larger than the oral. Short Y-shaped excretory bladder. Genital pore, dextral, in front of the ventral sucker. Testes more or less bean-shaped and tandem, each testis provided with a well-developed funiculus which leads forward.

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† Chatterji (1938) mentions that *Testifrondosa cristata* Bhalerao (1931) is synonymous with *Paryphostomum sufrartyae* Lane (1915) which comes under *Echinostomidae*.

into a vas deferens Receptaculum seminis absent A yolk reservoir present Uterine coils lie in front of the testes Vesicula seminalis retort-shaped, situated in front of the ventral sucker, cirrus short Vitellaria behind the ventral sucker and do not meet those of the other side posteriorly.

Type species—*Psilorchis indicus*

Key for the identification of the species of the genus *Psilorchis* reported from India

Cirrus sac adhering to the ventral sucker, ovary spherical .. *P. akgainis*

Cirrus sac separate from the ventral sucker, ovary oval . . . . *P. indicus*

### *Psilorchis indicus* Thapar and Lal, 1935

Body 8.57 mm × 1.17 mm, smooth cuticle without spines Oral sucker 1.7 mm. × 1 mm Ventral sucker situated in anterior 2/9th part of body, measures 7.5 mm × .65 mm Prepharynx 1.8 mm long, Pharynx 1.8 mm × 1.6 mm Oesophagus 0.9 mm. long Anterior testis 7.5 mm × 4.2 mm Posterior testis 7.5 mm × 3.6 mm. Ovary 4.1 mm × 2.5 mm Eggs large, oval, 12.5–13.0 mm × 0.8–1 mm.

Host — King-fisher (Intestine)

Locality — Lucknow

### *Psilorchis akgainis* Lal, 1938

Body 6.65 mm. × 7.5 mm, cuticle without spines Oral sucker 2 mm in diameter Ventral sucker 6.5 mm × 5.5 mm Pharynx 1 mm in diameter Oesophagus 12.5 mm long Anterior testis 6.5 mm × 3.75 mm Posterior testis .7 mm. × 4.25 mm Ovary 2.5 mm in diameter Eggs large, oval, 1–12.5 mm × .04–.05 mm

Host — *Nettion crecca* (Intestine)

Locality — Ajgain

### *Family Strigeidae* Railliet, 1919

The family Strigeidae was erected by Railliet (1919) for the forms previously included under Holostomidae Blanchard, 1847 and Hemistomidae Brandes, 1888 He further created a new superfamily Strigeoidea for the whole group having only one family, Strigeidae More recently a comprehensive study of the group in the form of a working classification

has been given by LaRue (1926) Under the family *Strigeidae*, he has listed five subfamilies, *Strigeinæ*, *Brauninæ*, *Cyathocotylinæ*, *Polycotylinæ* and *Alarinæ*

Poche (1925) excluded the subfamily *Cyathocotylinæ* from the family *Strigeidae* on the basis of presence of a cirrus sac and absence of the division of the body into two regions and erected the family *Cyathocotylidæ*. Szidat (1936) has further elaborated this view and has divided the family into several subfamilies. On the other hand, Bosma (1931) recognized the *Alaridæ* of Tubangu (1922) as a distinct family and Dubois (1933) divided it into three subfamilies.

But in spite of these modifications, the writer is still inclined to maintain the classification of LaRue (1926) as he considers that the differences between the various subfamilies of *Strigeidae* are not of such a great importance as to warrant their separation into different families.

#### *Diagnosis of the family Strigeidae Railliet, 1919 —*

The body is usually divided into two regions by a constriction, an anterior part bearing chiefly the special organs of attachment and a posterior part containing the major portion of the genitalia. The forebody is flattened or incurved ventrally or cup-shaped, the hind body is more or less cylindrical, ovoid or conical. The oral sucker is terminal or sub-terminal; the acetabulum is generally present but it is weak. The holdfast organ is situated posterior to the ventral sucker and is sometimes covering the latter. The intestinal cæca are without diverticula, usually extending to the posterior end of the body. Cirrus and cirrus sac present or absent. The vitelline glands are strongly developed. The uterus consists of few coils containing but few eggs.

The writer is giving below a key to the subfamilies of *Strigeidae* Railliet, 1919

- |    |   |                       |
|----|---|-----------------------|
| 1  | Cirrus sac present .. .   | 2                     |
|    | Cirrus sac absent ..  | 3                     |
| 2. | Body not divided into anterior and posterior part .. . .          | <i>Cyathocotylinæ</i> |
|    | Body more or less divided into anterior and posterior part .. . . | <i>Brauninæ</i> .     |
| 3. | Anterior part of the body cup-shaped                              | <i>Strigeinæ</i>      |
|    | Anterior part of the body flattened..                             | 4                     |

4	Uterus confined to hindbody and does not enter the holdfast organ . . .	Polycotylinae
	Uterus usually enters the holdfast organ . . . . .	Alariumæ

*Subfamily Cyathocotylinae* Muehling, 1898

*Diagnosis*—The body is short and broad, without division into distinct anterior and posterior regions. Cirrus and cirrus sac are present. The genital pore is situated at the posterior end of the body.

Type genus—*Cyathocotyle*

Only one species of the genus *Cyathocotyle* has been reported from India.

*Cyathocotyle calvus* Verma, 1936

Body 2.06 mm × 1.02 mm Oral sucker 0.15 mm × 0.19 mm, pharynx 0.09 mm × 0.097 mm, oesophagus and prepharynx absent Holdfast organ 0.32-·4 mm in diameter, wall covered with very peculiar characteristic, hair-like, fibrous outgrowths Testes very conspicuous, much elongated; anterior 0.56 mm × 0.18 mm, alongside holdfast organ; posterior 0.65 mm × 0.18 mm in narrower part of body, separated from the hind end by about half its length Ovary roundish, 0.28 mm in diameter, masked by vitelline follicles, anterolateral to hind testis Vitellaria grouped in large follicles of irregular shape along intestinal ceca meeting in front Cirrus sac 0.60 mm × 0.14 mm, contains coiled seminal vesicle, prostatic cells and a long tubular, eversible cirrus Genital atrium short, with male and female ducts opening side by side into it, genital pore postero-terminal Eggs about twice as long as thick, not many, 0.081-0.092 mm × 0.041-0.047 mm

*Host*—*Torgos calvus* (Intestine)

*Locality*.—Allahabad.

*Subfamily Polycotylinae* Monticelli, 1892

*Diagnosis*—Body divided into two regions, forebody flattened, hindbody cylindrical. Cirrus sac and cirrus absent Holdfast organ round, elliptical or bulbous Lateral wing-like suckers present or absent Genital pore posterior Uterine coils confined to hind body and never enter the holdfast organ

Type genus—*Polycotyle*

*\*Neodiplostomum dilacæcum* n. sp

A large number of these parasites were obtained from the small intestine of the spotted owllet, *Athene Brama* The body is flat and broad

\* A number of specimens of this form were also obtained from Dr. Thapar's collection.

and shows a clear division into a long anterior and a short posterior part. The posterior margin of the anterior portion of the body is produced into a thin flap which is placed transversely across the body and divides it into two parts.

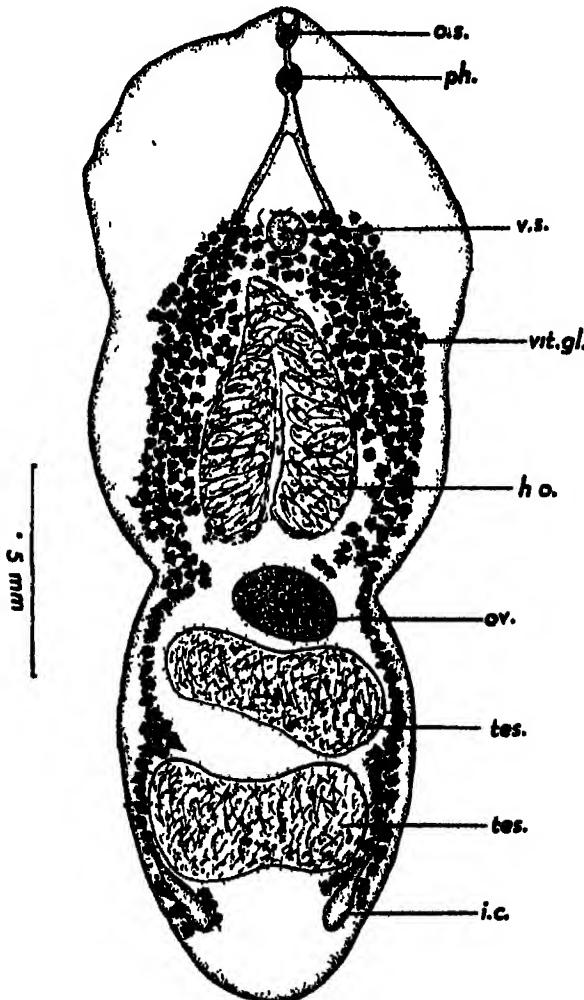


FIG. 18

*Neodiplostomum dilatatum* n. sp., entire worm—ventral view.

The length of the specimen is 2.35 mm, and its breadth is .9 mm. The anterior portion of the body measures 1.35 mm and the posterior portion 1.0 mm. The antero-ventral oral sucker measures .1 mm.  $\times$  .05 mm. The mouth leads into a narrow prepharynx which passes into a thick-walled

and muscular pharynx 075 mm  $\times$  05 mm in size. The oesophagus is short and bifurcates into the two intestinal cæca which run almost up to the posterior end of the animal terminating in greatly dilated, club-shaped ends.

The ventral sucker is muscular and measures 1 mm in diameter. The holdfast organ is a heart-shaped structure with its apex pointing anteriorly. It encloses a wide cavity in its posterior part. There is an inconspicuous adhesive-gland mass at the posterior end of the holdfast organ.

The gonads occupy the posterior half of the body. The ovary is elliptical and measures 25 mm  $\times$  15 mm. The ootype with shell-gland lies in between the testes. The uterus, starting from the ootype, takes an ascending course up to the level of the ovary. It then turns back in a descending loop and runs dorsal to the testes to the posterior end where it opens into the genital atrium. The eggs measure 1 mm  $\times$  05 mm.

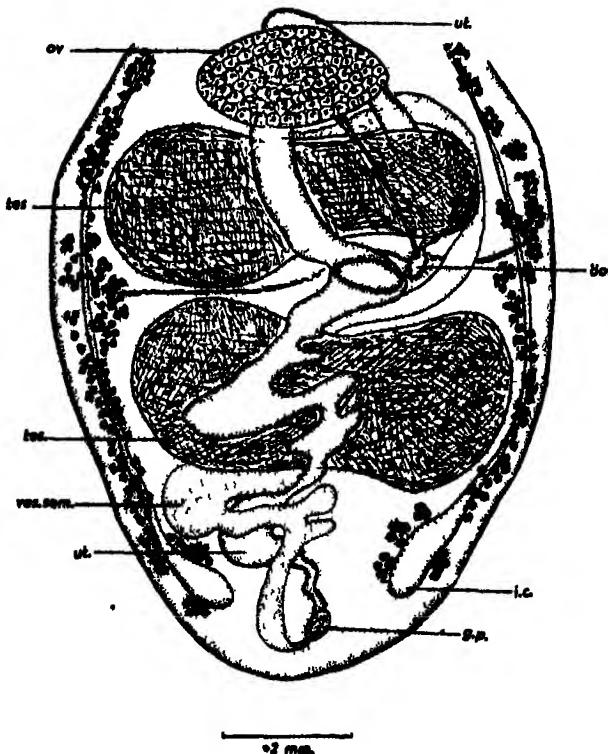


FIG. 14

*Nodiplostomum dilacrum*, Reproductive organs enlarged—dorsal view.

The testes, two in number, are broad and transversely elongated bodies. The anterior testis measures 525 mm  $\times$  275 mm and the posterior measures .5 mm  $\times$  3 mm. The vesicula seminalis is a thick convoluted structure lying behind the posterior testis and opening into the genital atrium along with the female duct.

The vitellaria are distributed throughout the anterior and the posterior part. Anteriorly they extend a little beyond the ventral sucker and fill up the entire space of the holdfast organ. Posteriorly they stretch up to the dilated cæcal ends.

**Remarks** —The form described above differs from all the species of the genus except *N. spathulaiforme*, *N. gavialis*, *N. orchilongum*, *N. cochleare*, and *N. Thomasi* in having a larger broad and flat anterior part of the body. But it differs from all these species in several points. From *N. spathulaiforme* and *N. gavialis* it differs in the absence of papillæ around the holdfast organ. It differs from *N. tytense*, in greater posterior extension of the vitellaria and the shape of the anterior testis. From *N. orchilongum* it differs in the position of the ootype which in *N. orchilongum* is rather peculiarly situated in front of both the testes. From *N. cochleare* it is distinguished in having a broad and flat posterior part of the body and in the absence of a cup-shaped union of the margin of the anterior part of the body. From *N. Thomasi* it differs in the shape of the posterior part of the body, in the shape of the testes, and in the absence of receptaculum seminis.

It is, thus, evident that this form stands apart from all the known species of the genus. It is further distinguished by the possession of a heart-shaped holdfast organ and greatly dilated and club-shaped cæcal ends. It is, therefore, designated as a new species.

#### *Neodiplostomum* sp.

A single immature specimen of this trematode was obtained from the intestine of the blue jay, *Coracias benghalensis*. The animal is 1 675 mm long and has the maximum breadth of .575 mm in the level of the holdfast organ. The body is distinctly divided into two parts. An extension of the posterior margin of the anterior portion overhangs the anterior end of the posterior portion of the body. The anterior portion of the body is .905 mm. long including the marginal expansion of .05 mm. The posterior part measures 82 mm long.

The oral sucker is oval in outline and measures .05 mm  $\times$  .07 mm. The mouth leads into a very short prepharynx which passes into a globular

muscular pharynx .031 mm in diameter. The Oesophagus is rather small and immediately divides into the two intestinal cæca.

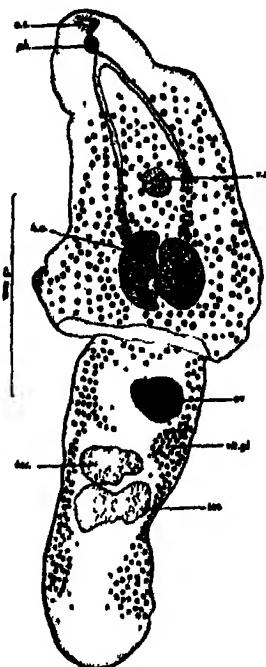


FIG 15  
*Neodiplostomum* sp — ventral view

The ventral sucker, which lies at a distance of .425 mm from the anterior end, measures 07 mm  $\times$  071 mm. The holdfast organ consists of two hemispherical pieces enclosing a cavity between them and measures 217 mm  $\times$  .185 mm.

The ovary lies at a distance of .08 mm from the anterior margin of the posterior portion of the body. It is an ovoid body, measuring 145 mm  $\times$  .11 mm.

The anterior testis which lies close to the posterior is .085 mm from the ovary and measures 17 mm  $\times$  .085 mm. The posterior testis measures .185 mm  $\times$  .11 mm.

The vitellaria extend almost throughout the body of the animal and consist of small follicles. No other details could be made out in the specimen.

**Remarks** — From the description given above, it is clear that the trematode belongs to the genus *Neodiplostomum* because of the division of the

body into two distinct parts, overhanging margin of the anterior part and absence of any lateral suckers at the anterior end. But in the absence of greater details of structure, it is not possible to assign any definite specific position to this trematode.

*Neodiplostomum tytense* Patwardhan, 1935

Body 2.82 mm long, divided into two unequal regions. Forebody flattened and measures 1.62 mm  $\times$  1.23 mm. Its lateral margins unite posteriorly to form a spoon-shaped depression. Hind body cylindrical and measures 1.2 mm  $\times$  .63 mm. Cuticle smooth. Oral sucker small, and measures .058 mm in diameter. Pharynx, small globular .062 mm in diameter. Oesophagus short. Acetabulum .087 mm in diameter. Holdfast organ, sub-circular, small, .294 mm. in diameter and lies 22 mm. behind ventral sucker. Ovary in front of testes at the junction of fore and hind body, ovate and measures .25 mm  $\times$  1.9 mm. Uterus and eggs not developed. Vitellaria consists of a large number of small follicles, scattered around the holdfast organ, and extend into the anterior third of hind body. Shell-gland situated near the left side at a level between the two testes. Testes, one behind the other, in the middle-third of hind body. Anterior testis pear-shaped, slightly to left and measures .375 mm  $\times$  .225 mm. Posterior testis deeply bilobed, and measures .45 mm.  $\times$  .225 mm. Vesicula seminalis large sac behind posterior testis. Genital pore at posterior end of body.

*Host* — *Tyto alba stertens* (Intestine)

*Locality* — Nagpur

*Proalaria alcedensis* Patwardhan, 1935

Body 2.24 mm long, divided into two parts. Forebody flattened measures .72 mm  $\times$  .66 mm. Hind body, cylindrical, and measures 1.52 mm.  $\times$  .5 mm. Oral sucker, terminal and measures .035 mm in diameter. On its either side are situated sucker-like prominences. No prepharynx. Pharynx spherical, muscular and .037 mm in diameter. Oesophagus short. Acetabulum, transversely ovate, .056 mm  $\times$  .048 mm in size. Holdfast organ slightly oval and invaginated posteriorly. It measures .175 mm  $\times$  .15 mm. A pair of adhesive glands are situated behind the holdfast organ. Ovary transversely oval situated considerably behind the junction of fore and hind body. It measures .125 mm.  $\times$  .1 mm. Vitellaria, of closely packed follicles, confined to anterior half of the hind body. Uterus extends a short distance in front of the ovary and contains a few but large eggs measuring .075 mm.  $\times$  .092 mm. Genital pore at posterior end of body. Testes lie in middle-third of hind body and occupy entire width. Anterior testis measures .5 mm.  $\times$  .325 mm. and posterior testis .4 mm  $\times$  .41 mm. Vesicula seminalis is voluminous and sac-like and lies behind the posterior testis. Details of cirrus, vesicula seminalis, pars prostatica not given.

*Host* — *Alcedo atthis* (Intestine).

*Locality* — Nagpur

*Neoalaria thaparia* n. g., n. sp.

About half a dozen specimens of this trematode were obtained from the intestine of the king vulture, *Sarcogyps calvus* at Lucknow. The animals showed active movements of the body which is flat and marked

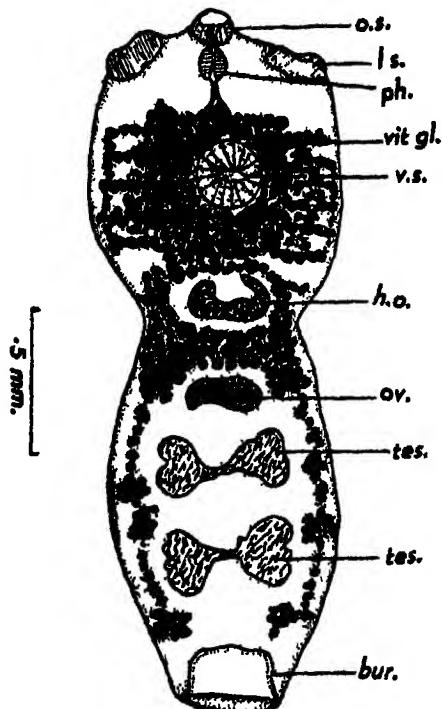


FIG. 16

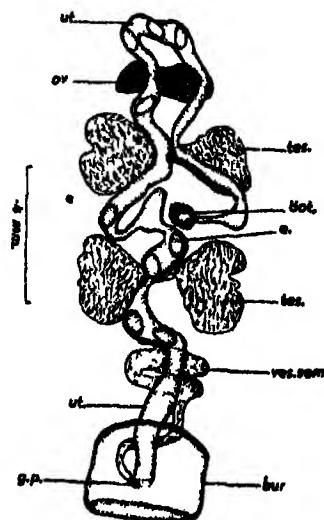


FIG. 17

FIG. 16.—*Neoalaria thaparia* n. g., n. sp.,—ventral view.

FIG. 17.—*Neoalaria thaparia*—reproductive organs enlarged—ventral view

off into two regions by a very inconspicuous constriction. The posterior end of the animal has a bursa which is shaped like an inverted cup. The writer has not been able to observe any sucker or papillæ inside the bursa

The length of the specimen is 2.45 mm. Its maximum width in the region of acetabulum is 9 mm. The anterior part of the body is roughly square in outline and is much smaller than the barrel-shaped posterior part

The oral sucker which projects a little beyond the anterior margin of the body measures 15 mm. x 125 mm. The mouth leads into an extremely small prepharynx which passes into the muscular pharynx

$\cdot 125 \text{ mm} \times \cdot 1 \text{ mm}$  The oesophagus is short and thin and bifurcates into the intestinal cæca at its posterior end

There are two wing-like lateral suckers situated by the side of the oral sucker. They measure 21 mm in length. The ventral sucker, almost circular in shape, is well developed and muscular and measures 25 mm in diameter. The holdfast organ is trough-shaped with thick wall and lies at the level of the demarcation of the body. There is no adhesive gland in this trematode.

The gonads are confined to the barrel-shaped posterior part of the body and lie in transverse plane parallel to each other.

The testes are peculiarly dumb-bell shaped and lie at a distance of 3 mm apart from each other. The anterior testis measures  $\cdot 5 \text{ mm} \times 25 \text{ mm}$  and the posterior  $5 \text{ mm} \times \cdot 275 \text{ mm}$ . The vesicula seminalis is thick and convoluted behind the posterior testis and opens into the bursa.

The ovary is elongated and is placed mesially, 15 mm ahead of the anterior testis. It measures  $\cdot 3 \text{ mm} \times 125 \text{ mm}$ . The ootype complex lies in between the two testes. The uterus runs in an ascending and a descending loop, a little ahead of the ovary but is confined to the posterior body and does not enter holdfast organ. It opens into the bursa along with the male duct. The eggs are thick-shelled and measure  $07\text{-}075 \text{ mm} \times 045\text{-}05 \text{ mm}$ .

The vitellaria also show peculiar distribution. They extend up to the level of oesophagus anteriorly and a little behind the testes posteriorly. They are closely arranged around the ventral sucker and the holdfast organ but towards the periphery they extend in chains, cutting clear parenchymatous spaces in between the chains. In the hinder part they are confined to the margins and do not extend into the middle of the body.

To sum up, the genus *Neoalaria* is characterised thus.

- 1 Trematodes with body, not distinctly divided into two regions  
There is no union of the posterior lateral margins of the fore-body. The anterior part of the body is roughly square, posterior barrel-shaped.
- 2 Ventral sucker larger than oral, lateral wing-like suckers present.
- 3 Holdfast organ trough-shaped, adhesive glands absent
- 4 Gonads lie parallel to each other in transverse plane
- 5 Testes peculiarly dumb-bell shaped.
- 6 Bursa without any sucker or papillæ.

- 7 Uterus, with ascending and descending loops, not entering the holdfast organ
8. Öotype complex in between the testes
- 9 Vitellaria marginal in posterior body, in anterior body, dense around ventral sucker and holdfast organ and extending in transverse chains towards the periphery and cutting clear parenchymatous tissue in between the chains
- 10 Eggs, thick-shelled

From the above, it is evident that the present form stands apart from all the genera of Strigeidae except *Alaria* and *Proalaria* in possessing lateral wing-like processes at the anterior end. It differs from *Alaria* in having its uterus behind the holdfast organ and in possessing a small trough-shaped holdfast organ and the absence of any union of the posterior lateral margins of the forebody. It differs from *Proalaria* in the absence of a clear division of the body into two parts and in the absence of adhesive gland. From both these genera it differs in having peculiar disposition of the vitellaria, dumb-bell shaped testes, bursa without sucker or papilla and peculiar shape of the body.

It is, therefore, regarded as a new genus for which the name *Neoalaria* is proposed with *Neoalaria thaparia* as the type species.

As the new genus resembles *Proalaria* in the disposition of the uterus, it is being included under the subfamily Polycotylinae.

#### *Subfamily Alarinae* Hall and Wigdor, 1918

Body indistinctly or distinctly divided into two portions, anterior part flattened, posterior part broad or cylindrical. Cirrus and cirrus sac absent. Holdfast organ cordate or elongated oval. Lateral suckers, tentacles or flaps usually present near the oral sucker. Uterus usually enters the holdfast organ.

Type genus—*Alaria*

#### *Pharyngostomum bagulum* N. Sp.

Two specimens of this Trematode were obtained from the intestine of the eastern grey heron, *Ardea cinerea rectirostris*. The body shows division into two parts although the constriction is only superficial. The anterior part of the body is flat and longer than the posterior part which is short and more or less ovoid in shape. The anterior part measures 63 mm and the posterior 35 mm in length. The lateral margins of the anterior part of the body do not show any union.

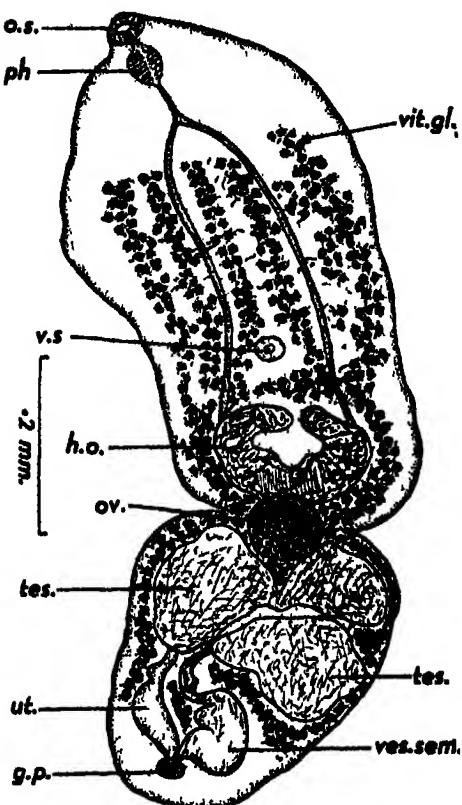


FIG 18  
*Pharyngostomum bagulum* n. sp.—ventral view

The mouth is surrounded by an oral sucker measuring .05 mm. by .03 mm and leads into an extremely small prepharynx which is followed by a globular pharynx  $05\text{ mm} \times 04\text{ mm}$  in size. The oesophagus is thin and divides at its posterior end into the two intestinal cæca which run up to the holdfast organ and are not visible behind it.

The holdfast organ is a peculiar thick-walled C-shaped structure with the mouth of the 'C' directed forwards. The writer has been unable to locate any adhesive gland which is apparently absent.

The ovary is median in position and lies at the constricted region of the body. It measures  $085\text{ mm} \times 075\text{ mm}$ . Close behind it are the two testes, the anterior is elongated and bilobed and measures  $.26\text{ mm.} \times .15\text{ mm.}$ , and the posterior is smaller and measures  $.175\text{ mm.} \times .12\text{ mm.}$

The vitellaria extend anteriorly up to the level of oesophagus ; posteriorly they are scattered and less numerous behind the testes

The uterus and vesicula seminalis open together into a genital atrium which lies a little distance in front of the posterior end. A mass of indistinct tissue behind the ovary is probably of the nature of ootype, shell-gland, etc., but it has not been properly identified. There are no eggs in the animal which appears to be an immature individual.

**Remarks** —The form described above comes under the family *Strigeidae* but does not possess either a cirrus sac or cup-shaped anterior body and hence cannot be included under the subfamilies *Cyathocotylinae*, *Brauniinae* and *Strigeinae*. The absence of both, clear demarcation into anterior and posterior part of the body and the union of the lateral margin of the forebody as also the presence of a thick and short posterior body, exclude it from the subfamily *Polycotylinae*.

The form, however, resembles the genus *Pharyngostomum* Cuurea, 1922, of the subfamily *Alarunae* in having a short and broad posterior body, the absence of united margin of the forebody, in the extension of the vitellaria up to oesophagus, in the nature of the intestinal cæca, position of the ovary, and a reduced acetabulum. Although the course of uterus could not be traced in the specimen, it seems probable that the uterus may enter the holdfast organ as it generally extends beyond the ovary which in the present case touches the holdfast organ.

But the present form differs from the described species of *Pharyngostomum* in having a posterior extension of the vitellaria, in the shape of the holdfast organ and in the almost entire margin of the testes. It is, therefore, being described as a new species.

#### Key for the identification of the *Strigeidae* included here

- 1 Cirrus sac absent .. .. 2
- Cirrus sac present . .. *Cyathocotyle calvus*
- 2 Uterus does not enter the holdfast organ .. .. 3
- Uterus enters the holdfast organ .. *Pharyngostomum bagulum*
- 3 Lateral suckers present .. .. 4
- Lateral suckers absent .. .. *Neodiplostomum* (see No 5).
- 4 Body not clearly divided into two parts; adhesive gland absent; testes dumb-bell shaped .. .. *Neolaria dumbellata*.

- Body clearly divided into two parts ;  
adhesive gland present .. .. *Proalaria alcedensis*.
- 5 Vitellaria extend up to the posterior end of the hind body, anterior testes broad and elongated .. *Neodiplostomum dilacatum*.  
Vitellaria extend only up to the anterior third of the hind body ; anterior testis pear-shaped .. *Neodiplostomum tytense*

*Family Schistosomidae* Looss, 1899

(Syn *Schistosomatidae* Poche, 1907, *Bilharziidae* Odhner, 1912)

The author has already elaborated on this family in a recent paper in the pages of these *Proceedings\** and has given a detailed history of the family.

*Diagnosis of the family Schistosomidae* —

*Trematoda* — Sexes separate, pharynx absent, oesophagus short, terminating posteriorly in a bifurcation to form intestinal branches or cæca which join ventrally at the cæcal union to form a single, slender intestinal cæcum terminating near the posterior end of the body. Suckers present or absent; acetabulum, when present, cephalad of the genital pore. Body of male may be widened caudad of the acetabulum and have the sides incurved ventrally, forming a gynaecophoric canal in which the female lies. Testes consist of four or more follicles. Cirrus pouch present or absent. Female more slender than male. Ovary elongate, sometimes spirally curved, and lying cephalad of the cæcal union. Laurer's canal present or absent. Vitellaria extensive, extending from the distal pole of the ovary to the posterior end of the body. Parasitic in the blood-vessels of birds and mammals.

The family *Schistosomidae* is divided into two subfamilies :—

1. *Schistosominæ* Stiles and Hassall, 1898
2. *Bilharziellinæ* Price, 1929.

*Key to the subfamilies of the family Schistosomidae*.

- Cæcal union caudad of equator of the body .. .. .. .. *Schistosominæ*  
Cæcal union cephalad of equator of the body .. .. .. .. *Bilharziellinæ*.

\* Vide *Proc. Ind. Acad. Sci.*, 1937, 6, No. 5, 274-88.

Subfamily *Schistosominae* Stiles and Hassall, 1898

*Diagnosis*—*Schistosomidae*—Males flattened and with the lateral edges of the body infolded ventrally to form a gynæcophoric canal Suckers present Intestinal cæca long, usually uniting caudad of the equator of the body, common cæcum relatively short Testes situated in the anterior or posterior half of the body, always cephalad of the cæcal union Females slender, thread-like, either longer or shorter than the males Uterus usually contains many eggs

Type genus—*Schistosoma* Weinland, 1858

Genus *Ornithobilharzia* Odhner, 1912

*Diagnosis*—*Schistosominae*—Female shorter than male Male with well-developed gynæcophoric canal, formed by an infolding of the lateral edges of the body Suckers present Cuticle covered with spines Digestive tract similar to that of *Schistosoma*, intestinal cæca long, showing a tendency to form several anastomoses before finally uniting to form the common cæcum Testes numerous, 60 or more, commencing a short distance caudad of acetabulum, and extending into posterior half of the body Cirrus pouch rudimentary or absent Seminal vesicle free in the parenchyma; prostate absent Genital pore situated immediately behind the acetabulum. Female elongate, slender and flattened. Ovary elongated, loosely or tightly coiled, and situated in anterior third of the body Vitellaria extensive, occupying about two-thirds of body length Laurer's canal present (at least in some species) Uterus short, containing only one egg at a time

Type species—*Ornithobilharzia intermedia*

*Ornithobilharzia* sp Gogate, 1934

Length 9.5 mm., breadth .488 mm. Spines and tubercles present on the body. Oral sucker .190 mm. in diameter. Ventral sucker pedunculated, 472 mm. x .417 mm. Intestinal cæca long, joining to form a common cæcum .52 mm from the posterior end. Testes about 70, circular, feebly developed Cirrus pouch rudimentary, posterior to ventral sucker Gynæcophoric canal well developed.

Host—*Dendrocygna javanica* (Clotted blood)

Locality—Rangoon

Remarks.—The author of this species found only two immature forms and gives no diagram of the specimens In the absence of an adequate account, the writer is unable to comment on this form.

*Subfamily Bilharziellinae* Price, 1929 emended

*Schistosomidae* — Suckers present or absent Gynæcophoric canal absent or imperfectly formed or sometimes well developed Paired intestinal cæca short uniting cephalad of the middle of the body, common cæcum long, with or without lateral dendritic branches Testes numerous and situated behind the cæcal union along the course of the common cæcum Uterus short, containing a single egg

Type genus—*Bilharziella* Looss, 1899

Key for the identification of the Avian Bilharziellinae reported from India :

Gynæcophoric canal well developed , ventral sucker present . . . . *Chinhuta indica*

Gynæcophoric canal absent , ventral sucker absent . . . . *Gigantobilharzia egreta*

Genus *Chinhuta* Lal, 1937

Male with a well-developed gynæcophoric canal, extending from a little behind the oral sucker up to the posterior end, female with flattened body and smaller than the male Suckers present Oesohagus provided with unicellular oesophageal glands The two intestinal cæca unite a little in front of the middle of body, common cæcum long, without lateral branches but provided with angular thickenings of its wall Testes vary between 70–80 in number and extend from the cæcal union to the posterior end of the animal Cirrus pouch well developed, enclosing a part of vesicula seminalis, prostate gland-cells, pars prostatica and the cirrus The terminal end of the cirrus sac is slightly bent to the left side The male genital pore lies slightly to the left of the median line near the middle of the body The ovary is elongated and sinuous, situated at the level of the cæcal union Uterus short and straight The female genital opening is a little behind the acetabulum Vitellaria situated on the sides of the common cæcum in distinct follicles A vitelline reservoir is present

Type species—*Chinhuta indica*

*Chinhuta indica* Lal, 1937

Male — 2.95 mm long, 3.75 mm. broad, lateral edges of body rolled inwards to form a deep groove Oral sucker weak 1 mm in diameter. Ventral sucker muscular ·15 mm in diameter Oesophagus ·375 mm long, with unicellular oesophageal glands Intestinal cæca join together

in the pre-equatorial region at a distance of 625 mm behind the ventral sucker and 1 275 mm from the anterior end Testes 70-80, oval bodies of variable size, largest .125 mm  $\times$  .04 mm, smallest .05 mm  $\times$  .025 mm Vesicula seminalis divided into two lobes, larger 117 mm  $\times$  0875 mm and smaller 087 mm  $\times$  07 mm

*Female* — 1 8 mm long, 19 mm broad Oral sucker .04 mm in diameter Ventral sucker .075 mm in diameter Oesophagus 225 mm long with unicellular oesophageal glands Intestinal cæca join together at a distance of 675 mm from the anterior end Ovary lies 27 mm behind ventral sucker and measures 155 mm  $\times$  .05 mm No eggs were found in the uterus Vitellaria distinct and large follicles posterior to ovary

*Host* — *Nettion crecca* (Main blood-vessels and internal organs)

*Locality* — Chinhut, Lucknow

#### Genus *Gigantobilharzia* Odhner, 1910

*Diagnosis of the genus Gigantobilharzia Odhner, 1910* —

*Bilharziellinae* — Female cylindrical and shorter than the somewhat flattened male Posterior extremity of both sexes provided with lateral lobe-like projections Cuticle without spines or tubercles Oral sucker present or absent Ventral sucker always absent Gynæcophoric canal absent or reduced to a short groove, situated in anterior part of the body Alimentary canal similar to that of *Bilharziella* Testes originate behind intestinal union and extend almost up to the posterior end of the body Cirrus pouch present Genital pore situated between the intestinal bifurcation and reunion Ovary moderately long and spiral Vitelline follicles occupy about nine-tenths of the body length Uterus short, containing a few eggs

Type species—*Gigantobilharzia acotylea* Odhner, 1910

#### *Gigantobilharzia egreta* Lal, 1937

*Male* — 38.85 mm long, 275 mm broad No oral or ventral sucker Oesophagus 1.2 mm long Cæcal union takes place .4 mm behind cæcal bifurcation Testes more than 600, filling 35.6 mm of body, size variable, largest 1.5 mm  $\times$  1 mm and smallest .075 mm  $\times$  .05 mm. Vesicula seminalis 2 mm in length

*Female* — Not obtained

*Host* — *Bulbulcus ibis coromandus* (Renal vein)

*Locality* — Lucknow

**Remarks**—Only two more species of this genus are recorded *G. acotylea* by Odhner (1910) from Sweden and *G. monacotylea* by Szidat (1930) from East Prussia.

#### HOST-PARASITE RELATIONSHIP

From a review of the habitat of trematodes in hosts, it is clear that the same species of trematode may sometimes infect more than one host. It is now a considered fact that the host-specificity theory of older helminthologists is no more an axiom. Cases have been reported of non-specificity of hosts in the trematodes affecting various groups of vertebrates. The writer (Lal, 1937) has already emphasised the non-specificity of hosts in trematodes and also referred to a work of similar nature on cestodes by Meggitt (1934). Even in the case of Avian Trematodes there appears to be no specificity of hosts in several cases. During his own investigations on the subject, the writer has come across examples where one species of trematode recorded from India infects more than one host. Thus, *Platynosomum acuminatum* has been described from Kestrel by Nicoll (1915) and from Crow by Bhalerao (1926). *Echinocasmus bagulari* has been obtained by Verma (1935) from two different genera of the Herons. *Prosthogonimus cuneatus* which is now reported from *Acridotheres tristis* has already been described from a large number of birds from Asia, Africa and Europe. *Echinostoma revolutum* has also been reported from an exceedingly large number of different hosts. It is, thus, evident that the host-specificity hypothesis does not strictly hold good for at least the Avian Trematodes.

#### COPULATION IN TREMATODES

The writer had no opportunity of making observations on the development of the Avian Trematodes described in the present communication, but he has been able to record a case of copulation in the genus *Levinsonella*.

The process of copulation has been observed in a large number of trematodes, both ecto-parasitic and endo-parasitic. Previous records reveal that the time of copulation varies with the individuals, and climatic conditions do not affect it specially in those cases where the host happens to be a warm-blooded animal. Several different methods of copulation have been observed from time to time in the case of Digenetic Trematodes. The fertilization is affected either through cross-copulation or self-copulation. The cross-copulation may be mutual or reciprocal, e.g., in *Prostlocus* (Looss, 1885), *Dicrocalym* (Linstow, 1890) and *Nematostrigea* (Nitzsch, 1819), where the terminal portion of the uterus or the metraterm serves as the vagina; or it may be one-sided copulation, e.g., in *Paragonimus* (Kerbert,

1881), *Liolope* (Cohn, 1902) and *Collyriclum* (Jegan, 1916) in which the Laurer's canal is said to function as vagina. In the case of self-copulation which also has been observed in some trematodes, e.g., in *Apopharynx* (Odhner, 1911) there is the introduction of the cirrus of the individual into its own metraterm.

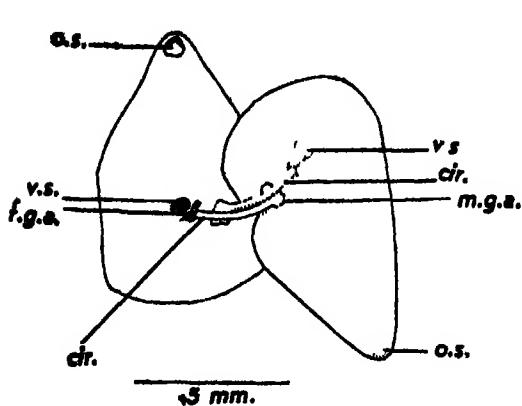


FIG. 19

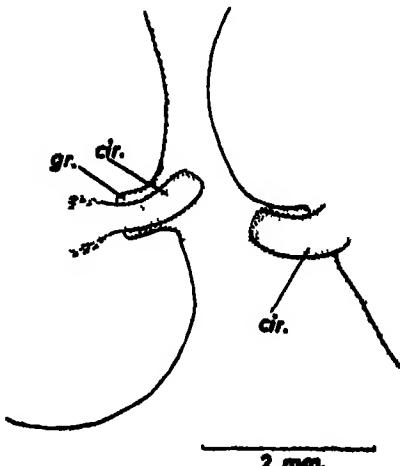


FIG. 20

FIG. 19. *Levinsenella indica*—copulating worms

FIG. 20 *Levinsenella indica*—showing retracted cirri and grooves

In the case of *Levinsenella indica* (Fig. 19) in which mutual copulation takes place, a pair of individuals were obtained in sexual congress when the bursa fabricii of the Jack snipe, *Gallinago gallinula*, was opened in normal salt solution. These trematodes being of small size, the fact of their recovery in a copulating state could not be definitely ascertained till the peculiarly shaped speck of tissue was subjected to examination under a low power of the microscope. The copulating individuals lie side by side, with their anterior ends pointing in opposite directions. One individual lies on its dorsal while the other on its ventral surface. The union takes place by the sides of the individuals which also partially overlap each other. A complete contact between the couple in the affected region is accomplished through the help of deep undulations in the neighbourhood of the cirrus. These undulations of the skin which take the form of grooves and papillae are developed on the affected sides of the individuals in the region of contact of their genital organs; and they appear to be temporary structures formed only during copulation as they are entirely absent in other specimens. Each papilla has one or two furrows on its side and the papillae

of one individual fits into the groove of the other and thus affords a firm hold for the trematodes. The cirrus of these individuals bears a large number of minute spines and those also help in maintaining the contact during copulation. In the present case the trematodes were so strongly attached to each other that the pressure of the cover-glass did not seem to have any effect.

The cirrus of each individual which is a thick cylindrical body apparently lengthens out very much and is thrust into the metraterm of the other. The male genital atrium lies at the base of the cirrus and during copulation its cavity, which normally contains the cirrus, is very much reduced by the contraction of its muscular thickenings. This exerts a pressure on the atrium and the cirrus is thereby pushed out.

An attempt was made to fix the specimens in the copulating state but the couple separated out and only their half retracted cirri (Fig. 20) could be observed in the fixed specimens. These observations on the copulation were made for about 20 minutes during which a camera lucida diagram was made. Since the parasites were recovered already in a copulating state, the author is unable to say anything definite regarding the duration of copulation.

#### GEOGRAPHICAL DISTRIBUTION

With regard to the distribution of the various genera of Avian Trematodes of India in relation to those found in other parts of the world, it may be mentioned that the distribution seems to be governed by the migration factor. The birds, most of which are migrants, foreign as well as local, can carry with them parasites which are peculiar to certain countries. These cases of hosts as carriers are very common. Certain cases of peculiar distribution are worth mentioning. The genus *Parorchis* was reported from Northumberland coast, St Andrews Millport, and America. It has now been obtained in India. Similarly the genus *Gigantobilharzia* which was reported only from Sweden and East Prussia is now being reported from India. The occurrence of *Parorchis*, *Gigantobilharzia* and certain other trematodes in India throws important light on the effect of the migratory hosts on the spread of helminthic infections. Some of these trematodes which were more or less endemic in particular countries have now been discovered in India, and as an explanation of this peculiar distribution it may be said that the parasites were brought to this country by the migratory birds. Some of these parasites would in course of time produce the eggs which may hatch out into miracidia and may infect the snails of a similar or closely similar variety as the original intermediate host. It is not

surprising that some of these miracidia may become adapted to their new environment and would thus produce cercaria which may infect new hosts. The usual barriers in case of land and sea animals do not control the infection in case of birds which can fly across continents and oceans and wander to distant places

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## LIST OF ABBREVIATIONS USED IN THE FIGURES

<i>bur.</i>	..	Bursa	<i>m.g.a.</i>	..	Male genital atrium.
<i>cir.</i>	..	Cirrus	<i>oes.</i>	..	Oesophagus.
<i>c.s.</i>	.	Cirrus sac	<i>ot.</i>	..	Ootype
<i>col.</i>	..	Collar.	<i>o.s.</i>	..	Oral sucker.
<i>e.bl.</i>		Excretory bladder	<i>ov.</i>	..	Ovary
<i>e.ch.</i>	.	Excretory chamber	<i>ph.</i>	..	Pharynx.
<i>e.p.</i>	.	Excretory pore	<i>r.e.</i>	..	Receptaculum seminis.
<i>f.g.a.</i>	.	Female genital atrium.	<i>tes.</i>	..	Testes.
<i>g.p.</i>	..	Genital pore.	<i>ut.</i>	..	Uterus
<i>gr.</i>	.	Groove	<i>v.s.</i>	..	Ventral sucker.
<i>h.o.</i>	..	Holdfast organ	<i>ves. sem.</i>		Vesicula seminalis.
<i>i.c.</i>	.	Intestinal ceca	<i>vit. d.</i>	.	Vitelline duct.
<i>l.s.</i>	..	Lateral sucker	<i>vit. gl.</i>	.	Vitelline glands
<i>met.</i>	..	Metraterm	<i>vit. res.</i>	..	Vitelline reservoir.

# LITTLE LEAF—A TRANSMISSIBLE DISEASE OF BRINJAL

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## Introduction

THE brinjal or egg plant (*Solanum melongena*) is an important vegetable crop in South India, its importance perhaps, being second only to that of the plantain (*Musa spp.*) It is grown all over the Presidency as an irrigated crop, either alone or mixed with other vegetables and often as a subsidiary crop in betel gardens As a pure crop it is grown in two seasons, one transplanted in July-August and the other transplanted in December-January. There are many local varieties which vary considerably in size, shape, colour and flavour Being a vegetable fancied by all classes of people, it commands a good market and a good crop will fetch in normal years a return of not less than Rs 300 per acre The crop is subject to the attack of a number of insect pests and fungus diseases, but so far, no virus disease has been recorded in South India In recent years a disease of obscure origin resulting in a gradual diminution in the size of the leaves and sterility of plants has been causing considerable damage to the crop in a number of places in the presidency, and this paper describes the disease and gives an account of the experiments carried out at Coimbatore in connection with its investigation

## History

The disease was first observed in the Central Farm, Coimbatore (Thomas) in 1937 when the investigation was first started Subsequently reports of the disease have been received at the Mycological Section from various parts of the presidency In 1938 the disease was observed in a virulent form at Nilampur, a village near Coimbatore, causing damage to an extent of nearly 50% of the crop in the field The disease would appear to be of virus origin Savulescu (1934) mentions a virus disease of brinjal in Rumania, which causes mottling of foliage and dwarfing, but the disease is apparently entirely different from the one described in this paper.

Smith (1937) does not mention the disease in the list of virus diseases attacking solanaceous plants Uppal (1929) mentions a mosaic disease of chillies which causes reduction of leaves and a similar disease of chillies has been noticed by Park (1934) in Ceylon Uppal's disease however would appear to be sap transmissible, while the Coimbatore disease is not Coleman's (1917) photographs of *Datura stramonium* indicate the possibility of a similar disease having been present in South India at the time But it is believed that no record of the disease as such, or a description of the disease has been made before \*

#### *Etiology*

Macroscopic and microscopic examination of a large number of affected plants did not reveal the presence of any constantly associated insect, fungus or bacterium that might be held to be the causative organism of the disease The absence of any living visible organism, was suggestive of a virus being the cause of the disease

#### *Symptoms of the Disease*

The disease has been noticed on brinjal and *Datura fastuosa* in nature

*Brinjal*—In brinjal the most characteristic symptom is the reduction in the size of the leaves As the disease progresses the new leaves produced become smaller and smaller with the result that in the course of a month the leaves are very considerably reduced The average size of a full grown leaf of a two-month old healthy plant is 10 cm × 16 cm and the maximum size of fully developed leaves of infected plants is 2 cm × 5 cm (Plate V, Fig 6) Both the petiole and the lamina are involved in the reduction, the leaves becoming almost sessile There is also considerable modification in the texture of the leaves In healthy plants the leaf is thick, leathery, hirsute, and dark green in colour In diseased plants the leaf becomes thin, soft, glabrous, and pale green in colour In thorny varieties, the thorns in diseased plants tend to get attenuated and in some cases entirely disappear owing to the disease

Another characteristic symptom is the stimulation of growth of axillary buds including the latent buds, accompanied by the shortening of internodes of the branches In course of time, the suppressed branches with numerous reduced leaves get crowded at the axils and the plant presents a characteristic bushy appearance (Plate V, Fig 5) At this stage the appearance of the plant is so entirely changed that it is difficult to recognise the original brinjal plant

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\* Dr. K M Smith in a letter to the senior author believes this to be so and has suggested that the virus be termed *Datura Virus 2*.

The third characteristic of the disease is the modification in the floral parts (phyllody) (Plate V, Fig 7) In many affected plants there is no trace of any floral parts being present, but whenever found these undergo teratological modifications, the corolla, androecium and gynoecium turning completely green (virescent) In cases where the disease makes its appearance after the flowers are normally formed, the flowers are shed and no fruits are set In very rare cases one or two fruits may develop normally As a rule however, affected plants are sterile and do not bear fruit at all The little-leaf affected plants are therefore absolutely worthless to the cultivator The disease affects the plants in all stages of growth, viz., from the seedling stage till the period of maturity

*Datura fastuosa* (Purple variety).—The disease occurs on this host in nature The symptoms are similar to those described in brinjal, namely, reduction in the size of leaves, shortening of internodes, crowding and stimulation of axillary branches (Plate VI, Figs 5 and 9) Phyllody is sometimes noticed but flowers are often normal and viable seeds are produced

*Datura fastuosa* (White variety) —In the white variety also the disease occurs in nature manifesting similar symptoms but phyllody of floral parts is common, and viable seeds are seldom formed The crowding of leaves in the axils is very noticeable (Plate VI, Fig 10)

*Tomato* —The disease has not so far been observed on this plant in nature, but has been induced by grafting The reduction in the size of leaves, stimulation of axillary buds and phyllody are characteristic symptoms Fruits when formed get mummified No viable seeds are formed The petioles and young shoots assume a purplish tinge (Plate VI, Figs 5 and 7)

*Tobacco* —The disease has not been observed in nature on tobacco but has been successfully induced from brinjal to tobacco by grafting (Plate VI, Fig 11) The changes brought about by the disease in this host are very marked The affected plants show all the characteristic modifications of virescence, reduction in the size of leaves and stimulation and crowding of axillary buds as in the case of brinjal, tomato and datura.

#### Varietal Susceptibility

So far as our present experience goes, all South-Indian varieties of brinjal appear to be susceptible to the disease It was not possible to distinguish varieties of brinjal by morphological characters as genetically pure types were seldom found In a preliminary experiment designed to test the varietal susceptibility of brinjal to the disease, 28 samples of seed from one source labelled as separate varieties and 8 samples from a firm of reputed seedsmen, were sown in pots, and the plants so raised were exposed to natural

infection. Plants which escaped infection were further artificially infected. The results (Table I) showed that all the varieties tested were susceptible to a greater or less degree.

TABLE I  
*Susceptibility of varieties of Solanum melongena to infection*

Variety		Number of plants tested	Number showing little leaf
Central Farm	8	.	7 each
"	9	.	"
"	10	.	"
"	11	.	"
"	13	.	"
"	14	.	"
"	16	.	"
"	17	.	"
"	18	.	"
"	19	.	"
"	20	.	"
"	21	.	"
"	22	.	"
"	23	.	"
"	24	.	"
"	25	.	"
"	27	.	"
"	28	..	"
"	31	.	"
"	32	..	"

TABLE I—(Contd.)

Variety	Number of plants tested	Number showing little leaf
Central Farm 33	,	3
" 34	,	2
" 35*	,	0
T C R	,	3
S 235	20 each	3
S 237 L W	,	3
S 238	,	2
S 239	,	2
S 240	,	3
S 241	,	3
S 242	,	4
S 245	,	3

\* Proved to be susceptible by grafting

#### Transmission Studies

##### Material and Methods —

*Original source of virus* Two affected plants collected from the Central Farm, Coimbatore, formed the original source of the virus

*Plants* — In a set of preliminary experiments the plants used were seedlings raised from seed obtained from a previous crop, which was not diseased. The plants were kept exposed and no attempt was made to keep them under insect-proof conditions. But in later trials, the seed was treated with ceresan, and sown in autoclaved soil in seed pans which were enclosed in muslin nets to prevent the entry of insects (Plate VI, Fig. 4) and throughout the period of growth all possible precautions were taken to grow the seedlings under insect-proof conditions.

*Inoculum* — Virus extract was obtained by crushing the leaves and tender shoots of affected plants in a sterilised agate mortar and expressing

the juice through folds of sterilised muslin Holmes' (1929) method of swabbing the surface of the leaf with the virus extract mixed with carborundum powder and Sein's (1930) pin-prick method were adopted for inoculation.

*Grafting*—This was done by the usual inarching method and the stock and scion were tied with raffia. After the lapse of a few days the stem of the scion was severed just below the graft.

*Budding*—This was done by the usual method of making a T-shaped cut in the bark of the stock and inserting a scion bud with a piece of wedge-shaped bark attached and tying up with raffia. Budding was successful only in a few cases and was given up for later experiments.

*Insect transmission*—The seedlings raised were transplanted after 28 days in earthenware pots filled with treated soil\* and immediately enclosed in glass lamp chimneys covered with muslin tops. The insects were either transferred directly from a diseased plant, or were enclosed in a glass tube and fed on a diseased plant for a period of not less than 24 hours prior to transfer. Aphids and tingids were transferred by means of a sterile camel hair-brush, taking care to see that the insects were not injured. No precaution was taken not to touch the leaf with the brush, as it was proved by sap inoculation experiments that the disease was not sap transmissible.

In the case of jassids, the insects previously fed on diseased plants were transferred to muslin-topped lamp chimneys which were subsequently placed over the healthy plants. It was found that sooner or later the insects settled down on the plant to feed. Six days after the transfer, the insects were killed by fumigating the plants with nicotine fumes or spraying them with a solution of nicotine sulphate. Care was taken to see that only one kind of insect was introduced at a time and in any series where an unknown insect was found inadvertently introduced, the series was rejected. As soon as the first symptoms of the disease were noticed the chimneys were removed and the plants were allowed to grow, under normal conditions. Considerable difficulty was experienced for want of an insect-proof glass-house but this was partially overcome by transferring the experimental plants, to the verandah of the laboratory in the main building which is 30 feet high from ground level and where owing to the absence of other vegetation nearby, infestation of insects other than those introduced was negligible. The controls remained healthy.

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\* The soil used was treated with boiling water poured twice over to kill all insects.

The number of plants used in each series of experiments throughout was not less than five of each kind unless otherwise mentioned. And each series was repeated thrice, so that the total number of plants used was not less than fifteen in any series.

#### Experiments and Results

*Sap inoculation*—Inoculation done as per the method described *supra* on the following host plants gave negative results—

*Solanum melongena*, *Datura fastuosa* (purple and white), tomato, tobacco and *Nicotiana glutinosa*

The experiment was repeated four times during different seasons of the year, and no case of transmission was noticed in any of the series.

*Grafting*—It was found that the disease was easily transmitted from brinjal to brinjal by means of grafting healthy stocks with affected scions. In the preliminary experiment in 1937 out of 23 plants grown in the pot-culture house four were grafted with diseased and 4 with healthy scions and 15 plants were left undisturbed. The four plants grafted with diseased scions took infection and developed symptoms of disease within 28 days, while the others remained free. Since then over 90 grafting transfers have been effected in the pot culture house at Coimbatore.

*Insect transmission*—Attempts were made to see if the following sucking insects found on brinjal in Coimbatore were vectors

- 1 *Aphis rumicis* Linn
- 2 *Aphis malvoidea* Das.
- 3 *Aphis gossypii* (Glov.)
- 4 *Empoasca devastans* Dis
- 5 *Eutettix phycitis* Dis
6. Thrips sp. (*unidentified*)
- 7 *Urentius echinus* Disk
- 8 *Phenococcus insolitus* Gr

Transmission experiments with the aphids and tingids gave negative results repeatedly.

TABLE II  
*Results of Insect Transmission Experiments*

Series	Source of virus	Transferred to	Name of the insect	Number of plants used	Number of plants infected
1	Brinjal	Brinjal	<i>Aphis rumicis</i>	6*	0
2	"	"	<i>Aphis malivoideis</i>	6*	0
3	"	"	<i>Aphis gossypii</i>	6*	0
4	"	"	<i>Uroleucon echinus</i>	6*	0
5	"	"	<i>Empoasca devastans</i>	6	1
6	"	"	<i>Eutettix phycitis</i>	6	2
7	"	"	do.	6	3
8	"	"	do	6	3
9	"	"	do	6	4
10	"	"	do.	3	2
11	"	"	Thrips sp	5*	0
12	"	Tomato	<i>Empoasca devastans</i>	3	0
13	"	"	<i>Eutettix phycitis</i>	8	0
14	"	Chillies	do	4	0
15	"	Datura	do	4	0
16	"	<i>S. xanthocarpum</i>	do.	6	3
17	Tomato	Brinjal	Thrips sp	3	0
18	"	Tomato	do.	3	0
19	"	"	<i>Phenacoccus insolitus</i>	3	0

\* Repeated four times

The results show that the two jassids—*Empoasca devastans* and *Eutettix phycitis*—could transfer the disease from brinjal to brinjal. Of these the

number of successful transfers effected by *Eutettix phycitis* was greater than those effected by *Empoasca devastans*. Both the jassids are of common occurrence in the brinjal fields in Coimbatore, and possibly are chiefly responsible for the spread of the disease in the field.

#### Host Range

The disease has been successfully transferred from brinjal to brinjal (cultivated and wild) tomato, tobacco *Datura fastuosa* and *Solanum trilobatum* by means of grafting. The results of these experiments are given in Tables III and IV.

TABLE III

*Results of Grafting Infected Scions on Different Hosts*

Source of virus	Host plant	Method	Result	
			Number of healthy plants used	Number of plants infected
Brinjal	Brinjal	Grafting	90	90
"	," (wild)	"	7	6
"	<i>Datura</i> (purple)	"	6	5
"	Tomato	"	15	13
Tomato	"	"	3	3
<i>Datura</i>	Brinjal	"	5	3
," (purple)	Tomato	"	5	2
," (white)	"	"	5	nil
Brinjal	Tobacco	"	5	4
"	<i>Santalam album</i>	"	2	nil
"	<i>Solanum trilobatum</i>	"	1	1

TABLE IV  
*Period required for development of symptoms*

Nature of infection	Method of transmission	Time taken for symptoms to appear
Brinjal to brinjal	Insect	24 to 45 days
" "	Grafting	21 to 30 "
" <i>datura</i>	"	"
" tomato	"	15 to 22 "
Tomato to "	"	16 to 20 "
Brinjal to tobacco	"	40 "

#### *Seed Transmission*

An attempt was made to see whether the disease is transmissible through seed. Two lots of seed collected from partially diseased brinjal and *Datura fastuosa* plants were sown under insect-proof conditions. No disease was noticed in the seedlings. It would appear therefore that the disease is not seed transmissible.

#### *Control*

Destruction of all solanaceous weeds from gardens and prompt removal of affected plants would appear to be the only possible means of keeping the disease in check until resistant varieties are found. In a field where the weeds were completely eradicated and the diseased plants rogued out the subsequent incidence was reported to be markedly less than in the other fields in the same locality.

#### *Summary*

A transmissible disease of *Solanum melongena* has been found to cause considerable damage to the crop in many parts of the Madras Presidency. The general nature of the symptoms together with the absence of a visible associated organism was suggestive of a virus being the cause of the disease. Owing to the complete suppression of the productive phase in the affected plants and the high percentage of incidence the loss is very great. The disease is found to be transmissible to *Datura fastuosa*, tomato, tobacco and wild brinjal, *S. xanthocarpum* and *S. trilobatum*.

The disease is not transmissible by sap inoculation but is easily transmitted by means of grafting. Two species of jassids would appear to be vectors of the disease.

#### Acknowledgements

The authors are greatly indebted to Dr K M Smith, F.R.S., for examining preserved material and photographs of the disease and to Mr M C Cherian, Entomologist to the Government of Madras, for identifying the insects mentioned in this paper.

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#### DESCRIPTION OF PLATES

##### PLATE V

FIG 1.—View of a brinjal field in a village near Coimbatore showing large number of affected plants

FIG 2.—Healthy and naturally infected brinjal plants of the same age

FIG 3.—A healthy brinjal plant

FIG 4.—Brinjal plant showing symptoms of disease induced by grafting

FIG 5.—Same plant showing advanced stage of disease

FIG 6.—Terminal shoot of a diseased plant showing the reduction in the size of leaves  
Leaves from the healthy plant of the same age on the right

Figs. 7, 8 and 9.—Modification of floral parts brought about by the disease in brinjal  
Healthy flower on the left in Fig 7

FIG. 10.—Modification of floral parts in *Datura fastuosa*

FIG. 11.—Mummified fruit of infected tomato plant showing characteristic splitting.

FIG. 12.—Modification of floral parts in tobacco and tomato :—

Top : Tobacco flowers healthy (left) and infected (right).

Bottom : Tomato flowers infected (left) and healthy (right)

## PLATE VI

FIG 1 - A brinjal seedling (left) showing symptoms of disease transferred by the insect *Eulettix phycitae* fed on diseased shoots Control—healthy plant on the right

FIG 2 —Same plant two months later (Control not in the picture)

FIG 3 - (1) Brinjal seedling 28 days old (control)

(2) .. .. .. infected by *Eulettix phycitae*

(3) .. .. 2 months old infected by *Eulettix phycitae*

FIG 4 —View of insect-proof cages in which seedlings were raised for the experiments

FIG 5 —Showing diseased plants (left to right) of brinjal, tomato, *Datura fastuosa* (purple) and *Datura fastuosa* (white)

FIG 6 —*Solanum melongena* (wild) showing the disease induced by grafting

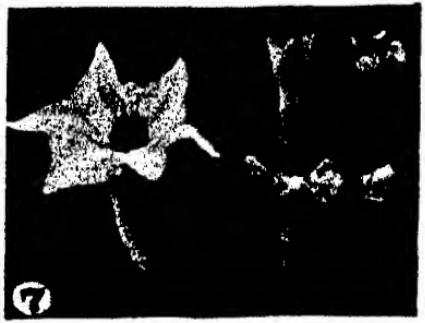
FIG 7 —Showing healthy (left) and diseased (right) tomato plants (var Golden queen)  
Disease transmitted from brinjal by grafting

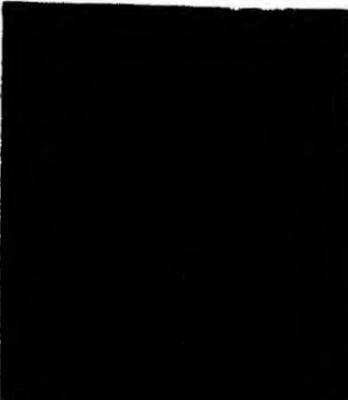
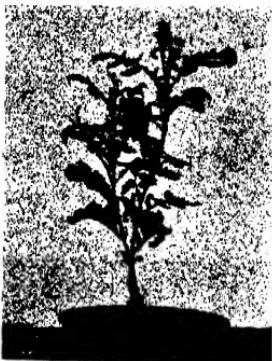
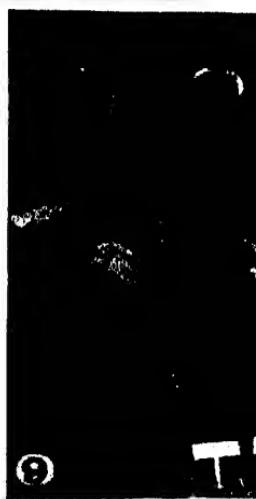
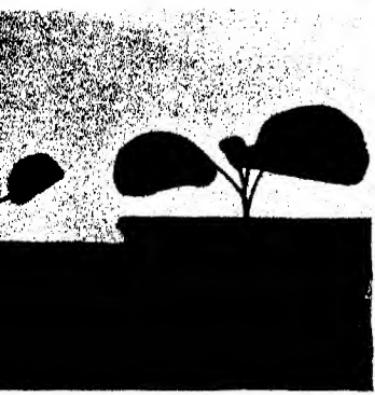
FIG 8 —Diseased tomato plant (var Dwarf giant)

FIG 9 - *Datura fastuosa* purple variety showing healthy plant (left) and infected plant (right)

FIG 10 —*Datura fastuosa* (white) healthy (extreme left), showing symptoms in early stage (middle) and showing symptoms in advanced stage (extreme right)

FIGS 11 and 12 —Tobacco plants (variety Harrison special), showing disease induced by grafting





## TESTICULAR OVA IN *URAEOTYPH PLUS* *NARAYANI SESHACHAR*

BY B R SESHACHAR

(From the Department of Zoology, University of Mysore, Central College, Bangalore)

Received August 2, 1939

(Communicated by Prof A Subba Rau)

OVA in the testis of Amphibia have been reported by a number of workers both normally as well as during implantation experiments. In the toads, however, they have been more frequently found than in other Amphibia. The development of the Bidder's organ in many species of *Bufo* is probably the culmination of this faculty to develop ova by the male. The development of the Bidder's organ and its probable function have formed the subjects of numerous memoirs to which that of Witschi (1933) is probably the latest contribution helping to elucidate many obscure points in regard to this peculiar organ.

While the development of ovarian structures in species of Amphibia other than *Bufo* is comparatively rare, Swingle (1917), Crew (1921) and Rau and Gatenby (1923) have described in various species of *Rana* isolated ova in the testis of both adults and larvae. The last-mentioned authors noticed in a male specimen of *Rana temporaria* a structure resembling the Bidder's organ.

The presence of ova in relation to the testis is more common in experimental work. Meyns's (1910) classic experiments on transplantation of testis in frogs yielded results which pointed generally to the fact that in transplanted and regenerating testis fragments, eggs are commonly found. These observations have been substantiated by the work of Ponse (1924) on *Bufo vulgaris* and later by Welti (1928) in the same species. But contrary results have been reported by Lauche (1915) in *Rana*, Witschi (1925) in *Bufo* and Moszkowska (1932) in *Bombinator*. No eggs were found by these authors in the testicular implants.

Champy (1921) has produced precisely similar results by different means. In a specimen of *Triton alpestris*, starvation produced a suppression of spermatogenesis but when later the specimen was fed, the gonocytes of the starved male gonad had metamorphosed into oocytes and the individual in every way resembled a female.

A review of the existing literature reveals nothing regarding this problem in *Apoda*. So far as I am aware, a Bidder's organ has not been noticed in any example of this group nor have testicular eggs been reported, either normally or as a result of experimental work.

So the interest attached to the discovery of testicular eggs in a member of the *Apoda* is considerable. During my study of the spermatogenesis of *Uræotyphlus narayanii*, I came across a set of sections of the testis showing eggs. Three such ova were found in the different lobes of the testis of the same animal. The following is a brief description of the ova.

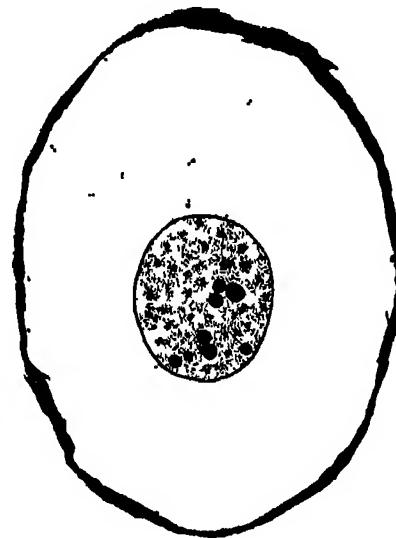


FIG. 5

The ova are all intratubular. They are large and all the three are of about the same size and in about the same stage of development. The cells present all appearances of typically developing ova of the female. The nucleus appears to be in the germinal vesicle condition. No distinct chromosomes nor a nuclear network can be seen. The nucleus takes an almost uniform dark stain. An interesting feature is the presence in the nucleus of each ovum, of a large number of nucleoli. They vary from 15 to 27 in number. This is another feature in which the testicular ova resemble normal ova of the female, where also multiple nucleoli are met with. At least in one of the ova, the nucleoli are extruded into the cytoplasm and a number of them occur scattered all over the cytoplasm (Fig. 6). An extrusion of nucleoli into the cytoplasm is common in normal ova also. In one of the

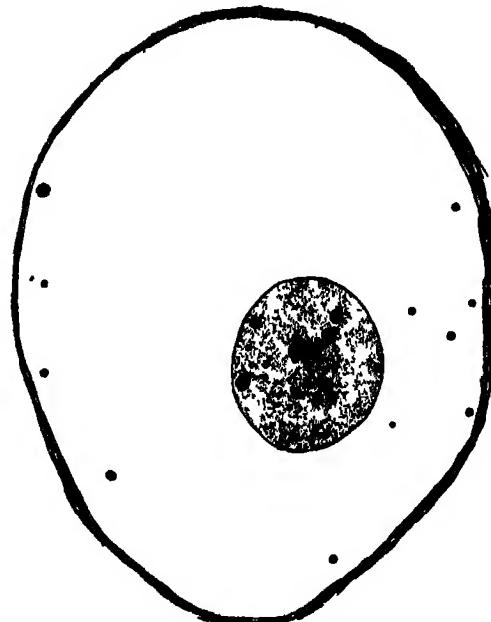


FIG. 6

oocytes a cap of granules is found in relation with the nucleus (Fig. 7) I believe these are mitochondrial granules It is obviously hazardous on my

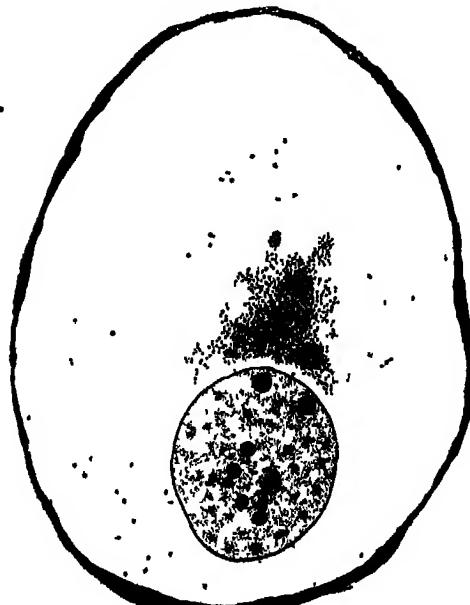


FIG. 7

part to attempt to discuss the cytology of these cells, seeing the paucity of the material at my disposal and also the absence of any particular methods for this type of cytological work (the material was fixed in Flemming's fluid with acetic acid and later the sections were bleached in hydrogen peroxide for the study of the chromosomes) However, a few tentative conclusions can be arrived at as a result of the examination of the material at my disposal The Apoda obviously fall in a line with other Amphibia, especially with the Anura, in the occurrence of oocytes normally in the testis Witschi (1934) has discussed at length the origin of such oocytes in normal adult testis in Anura and assigns two important reasons for their occurrence (1) A passive conveyance of the eggs from the cortex to the medulla by the sex cords in young specimens belonging to sex races of the undifferentiated type , and (2) A transformation of primitive gonia into ovicells by their enlargement and by a change in their nuclear organization Ova which have been derived by the latter method are usually intratubular This transformation has been called 'oviform degeneration' I believe the ovicells found in the testis of *Uræotyphlus narayani* belong to the second type and have been formed by a transformation of primitive gonia The oocytes probably degenerate

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FIG 1



FIG 2

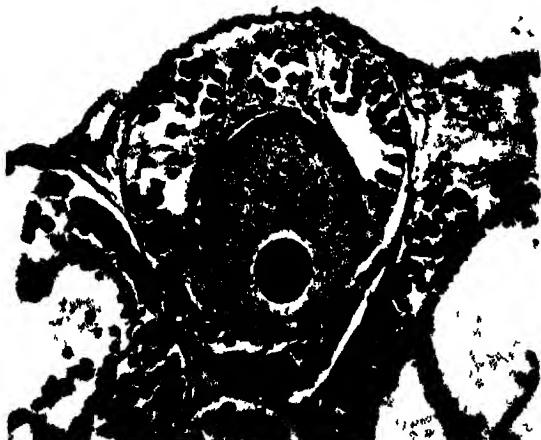


FIG 3



FIG 4



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## EXPLANATION OF FIGURES

- FIG 1. Photomicrograph of the longitudinal section of a testis lobe of *Uraeotyphlus narayani* showing an ovicell in one of the locules of the testis  $\times 38$
- FIG 2. The ovicell enlarged to show the multiple nucleoli  $\times 165$
- FIG 3 Photomicrograph of another ovicell showing an aggregation of what are probably mitochondria in relation with the nucleus  $\times 165$
- FIG 4 Photomicrograph of the third ovicell  $\times 165$
- FIG 5 Drawing of the ovicell seen in Figs 1 and 2  $\times 533$
- FIG 6 Drawing of the ovicell seen in Fig 4 showing the distribution of the extruded nucleoli in the cytoplasm  $\times 533$
- FIG 7 Drawing of the ovicell seen in Fig 3 showing the distribution of the mitochondrial granules in relation with the nucleus  $\times 533$

## TWO NEW ADDITIONS TO THE LIST OF THE INDIAN ASPERGILLI

By COL I FROILANO DE MELLO

(From Medical College, Nova Lâda)

Received May 30, 1939

To the list of the Indian Aspergilli given by Chaudhuri and Umar<sup>1</sup> I will add two species, hitherto not recorded in Indian flora

They have been found as saprophytes in the scrapings of the first case of chromoblastomycosis found by me in India, and provenient from Karachi, where the patient saw the beginning of his lesions since some ten years ago

The cultures were obtained primarily in petri-dishes of glucosized and maltosed Sabouraud and have been sent to the mycological collection of Central Bureau voor Schimmelcultures, Baarn Holland, where they are kept

*I Aspergillus japonicus* Saito (*Bot Magazine*, Tokyo 1906, 20)

*Cultures Maltosed Sabouraud* On the 2nd and 3rd day the culture has a white dirty, somewhat brownish tone On the 4th day the colour resembles coffee powder From the 5th day forwards the culture takes a somewhat violet stain

*Glucosized Sabouraud* idem

*Plain agar* very weak development

*Potato* idem ut *Sabouraud*

*Milk* on 4th day a greyish membrane at the surface, soon covered by a coffee violet powder

*Measurements Conidiophores* max 572 6 microns, min 264; *Columella* (expanded extremity of the conidiophore which supports the *Sterigmata*) generally ovoid, with the large diameter measuring 26 to 43 microns and the small one a little more than half of these dimensions; *Sterigmata*, single, 6 5, *Conidia*, round 2 6, *Head* (*columella + sterigma + conidial chain*) max 118, min 46

This species which resembles *A niger* and *A atropurpureus* Zimm. differs from them by its sterigmata which are simple and by its colour

which, being, first, dirty white with a brownish tone, becomes at least of coffee powder colour with violet reflexes

The work of the cultures, drawings and measurements has been done with the collaboration of my pupil Barboza Barreto, to whom my thanks are due

*II Aspergillus carbonarius* Bain (*Bull Soc Bot Fr*, 1880, 27)

*Cultures Maltosed Sabouraud* whitish, cotton-like on the 2nd day, with some black points scattered on the surface, since the 3rd day, and becoming entirely black with erect conidiophores of 1 to 2.5 mm visible at naked view, supporting blackish heads resembling chimney black

*Glucosed Sabouraud* idem *Plain agar nihil Potato, simple* and *glycerinated idem Carrot* idem *Glycerinated carrot nihil Liquid media* (milk, Langeron, Bouillon, Vegetable Bouillon)-surface soon covered by black powdery and very thick layer of heads and spores

*Measurements Conidiophores* max 2500 microns, min 350, *Columella* round and ovoid Diameter of the round ones 90 Dimensions of the ovoid ones 75/50, *Conidia* membrane warty, 4 to 5 microns diameter, *Sterigmata Primary* 6-7 microns, *Secondary*, very small and hardly visible, *Heads* max 300, min 200

*N B* —In both these species perithecia were not found

Inoculated to rats and rabbits subcutaneously, intraveinously and intraperitoneally, both these Aspergilli were found innocuous

The cultures, drawings and measurements of this species have been done with the collaboration of my pupil Estevam Afonso, to whom my best thanks are due

*Resumé* To the list of Indian Aspergilli, recorded by Chaudhuri and Umar in 1938, two more species are added *A. carbonarius* Bain, 1880, and *A. japonicus* Saito, 1906

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# COMPOUNDS OF PHOSPHORUS IN MILK—I

By B N ACHARYA, M Sc

AND

S C DEVADATTA, D Sc (EDIN.)

(From the Chemistry Laboratories, Wilson College, Bombay, 7)

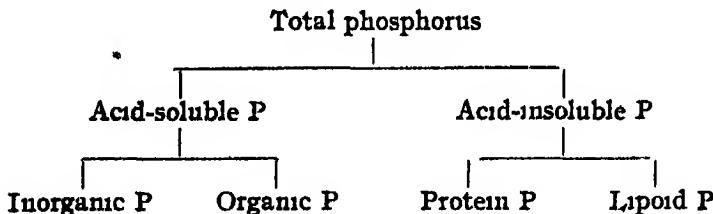
Originally received October 14, 1938

Received in revised form August 5, 1939

ALTHOUGH phosphorus compounds of milk have been investigated by many in the field, their classification and general nature are still incomplete and obscure

Jordan Hart and Patten<sup>1</sup> have estimated the total phosphorus in the whole milk and in its acid-soluble portion, they have also estimated the amount of organic phosphorus in the acid-soluble portion

Lenstrup<sup>2</sup> states that there are four different forms of phosphorus compounds in milk which can be estimated



He separated the acid-soluble phosphorus compounds from the acid-insoluble by picric acid. Inorganic phosphorus is then precipitated from the acid-soluble fraction by adding ammonia-magnesia mixture, leaving organic phosphorus in the solution. He analysed the acid-soluble fraction and the portion containing organic phosphorus.

Luddecke<sup>3</sup> found that picric acid in cold slowly attacks lecithin on standing. Therefore Graham and Kay<sup>4</sup> used trichloracetic acid as a precipitant instead of picric acid. In their paper (*loc cit*) they state that their values for inorganic phosphorous are vitiated by the possibility of the

<sup>1</sup> Amer J. Physiol., 1908, 16, 268.

<sup>2</sup> J. Biol. Chem., 1926, 70, 193.

<sup>3</sup> Inaugural Diss. Munich, 1905.

<sup>4</sup> J. Dairy Res., 1933, 5, 54-62-63-74.

organic phosphorus from compounds of the type phosphagen, decomposing in presence of strong acids

W. Hochheimer<sup>a</sup> found hexose mono-phosphoric acid, pyrophosphate and adenosine triphosphoric acid in cow's milk

An attempt to find the nature of phosphorus compounds in the buffalo's milk available in Bombay City, is made in this communication

### *Experimental*

Compounds of phosphorus in the acid-soluble portion of milk were estimated by employing the methods developed by Eggleton and Eggleton<sup>b</sup> for muscle tissue, with some modifications

To obtain the acid-soluble portion of milk, 0.5 c.c. of milk was taken in a centrifuge tube, 2.5 c.c. of water and 2 c.c. of 25 per cent trichlor-acetic acid were added, and centrifuged. The acid extract was neutralised by the addition of finely ground baryta until neutral to phenolphthalein (*i.e.*, pH = 9). The mixture was centrifuged and decanted. The liquid separated from the precipitate is called Fraction B. The precipitate (Fraction A) was dissolved in a drop of concentrated hydrochloric acid and diluted to 10 c.c. with water.

*Fraction A*—The orthophosphate was detected by Brigg's method before any hydrolysis had set in. The pyro- was estimated by Lohman's method<sup>c</sup>. The organic phosphorus was looked for after the solution was oxidised by sulphuric acid and 100 volume hydrogen peroxide, and hydrolysed. In all estimations a quantity of solution expected to contain 0.15 to 0.2 mg. of phosphorus was used.

*Fraction B*—This contains hydrolysable and non-hydrolysable organic phosphorus compounds soluble in barium hydroxide at pH 9.

*Hydrolysable phosphorus*—To estimate the amount of phosphorus associated with the hydrolysable organic compounds, the solution was hydrolysed with 2 c.c. of 5.5 N Sulphuric acid for sixty minutes at ordinary temperature before the application of Brigg's method.

*For Non-hydrolysable phosphorus*, the total amount of phosphorus in this fraction was estimated by the method of oxidation and hydrolysis referred to already. The difference between this amount and that due to the hydrolysable variety gives the amount of phosphorus associated with the non-hydrolysable organic phosphorus compounds.

<sup>a</sup> *Kinderheilk.*, 1932, 54, 49-64.

<sup>b</sup> *J. Physiol.*, 1929, 68, No. 2, 193.

<sup>c</sup> *Biochem. Zeit.*, 1928, 208, 172.

*Whole milk and the acid-insoluble portion of milk were separately oxidised and after complete hydrolysis, Brigg's method was applied for the estimation of phosphorus. We have been able to check up the values obtained by direct estimations by comparing with those obtained indirectly, i.e., by difference.*

The acid-insoluble portion of milk was analysed for *lipoid phosphorus* and *casein phosphorus*.

For the estimation of lipoid phosphorus the method adopted was that of Graham and Kay (*loc. cit.*)

Casein in milk was obtained by Hammerstein method,<sup>8</sup> and the phosphorus content in it was estimated by subjecting it to oxidation and hydrolysis as in the case of whole milk.

### Results and Discussion

TABLE I

#### Composition of Milk

(In gm per 100 c.c. of Milk)

Expt	Sp gr at 30°C	Total Solids	Fat	S N F	Casein	Lactose	Ash	Chloride
1	1.029	17.80	8.50	9.30	3.42	4.92	0.721	0.0648
2	1.028	16.36	8.36	8.00	3.13	4.95	0.703	0.0623
3	1.030	20.44	9.24	11.20	3.92	4.90	0.810	0.0729
4	1.030	21.63	9.63	12.00	4.18	4.55	0.862	0.0766
5	1.030	20.36	9.45	10.91	3.98	4.65	0.803	0.0723
6	1.031	21.66	9.70	11.98	4.26	4.29	0.864	0.0778
7	1.031	21.66	9.70	11.98	4.28	4.23	0.861	0.0775
8	1.030	18.63	7.37	10.93	3.88	4.98	0.765	0.0689
9	1.030	19.20	9.48	11.98	3.83	4.98	0.793	0.0720
10	..	21.36	8.91	11.03	4.06	4.94	0.801	0.0723
Average	1.030	19.03	9.03	10.91	3.87	4.74	0.798	0.0717
Standard deviation	0.000	±0.20	±1.8	±1.015	±1.048	±0.24	±0.048	±0.0025

S N F = Solids not fat

<sup>8</sup> Z. Physiol. Chem., 1883, 7, 227, 1885, 9, 273.

TABLE II  
*Analysis of Ash of Milk*  
 (In gms per 100 c.c. of Milk)

Expt	Ash	Calcium	Phosphorus	Ratio CaO/P <sub>2</sub> O <sub>5</sub>
1	0.721	0.1521	0.0800	1.161
2	0.703	0.1482	0.0710	1.276
3	0.810	0.1717	0.0820	1.091
4	0.862	0.1828	0.0873	1.279
5	0.803	0.1723	0.0803	1.309
6	0.864	0.1830	0.0875	1.278
7	0.861	0.1828	0.0874	1.279
8	0.765	0.1603	0.0775	1.272
9	0.793	0.1673	0.0790	1.290
10	0.801	0.1698	0.0802	1.294
Average	0.798	0.2325 (as CaO)	0.1895 (as P <sub>2</sub> O <sub>5</sub> )	1.253
Standard deviation	± 0.048	± 0.20	± 0.036	± 0.071

TABLE III  
*Analysis of Compounds of Phosphorus*  
 (Percentage of Total Phosphorus)

I		II		III		
No	Acid-soluble	Fraction B		Fraction A		
	P	Early hyd P	Non hyd P	Non hyd P	Ortho-P	Pyro-P
1	78.27	9.22	4.88	9.50	42.39	13.81
2	75.50	7.88	4.68	8.91	39.87	12.59
3	75.90	9.49	4.77	8.64	39.82	14.13
4	78.50	9.00	4.65	8.72	41.09	12.88
5	77.26	9.66	4.90	9.57	40.10	13.06

(Hyd = Hydrolysable)

TABLE IV  
Concentration of Different Types of Phosphorus  
(In mg per 100 c.c. of Milk)

	1	2	3	4		5		
Expt.	Total phos- phorus	Total acid- soluble P	Total acid- insoluble P	FRACTION B		FRACTION A		
				Easily hyd P	Non hyd P	Non hyd P	Ortho- P	Pyro P
1	110.63	86.10	24.20	10.20	5.40	10.52	46.90	15.28
2	128.56	97.10	31.26	10.14	6.02	11.50	51.26	16.18
3	120.10	91.20	27.32	11.40	5.73	10.38	47.83	16.97
4	106.83	83.90	21.98	10.50	7.10	9.32	43.89	13.76
5	124.90	96.50	27.63	12.07	6.02	11.95	50.09	16.32
6		98.33		12.30	6.14	12.20	51.26	15.20
7		78.60		9.83	4.91	9.76	40.56	12.15
8		76.44		9.50	4.77	9.48	39.84	11.81
9		83.92		10.42	5.19	10.32	42.89	12.86
10		74.46		9.21	4.65	9.24	38.45	11.15
11		78.90		9.86	5.01	9.70	41.29	12.20
12		79.96		9.99	5.99	9.999	41.99	12.36
13		86.40		10.87	5.39	10.72	45.10	13.36
14		96.32		12.04	6.01	11.95	50.12	14.89
15		95.45		12.00	5.96	11.84	49.62	14.75
Average	118.20	86.87	26.48	10.70	5.62	10.00	45.4	13.95
Standard deviation	± 2.65	± 2.98		± 0.98	± 0.63	± 0.95	± 1.34	± 1.61

TABLE V  
*Acid-insoluble Fraction of Milk*  
*Concentration of Different Types of Phosphorus*  
 (In mg per 100 c.c. of Milk)

Expt	Total P	Total acid insoluble P	Casein P	Lipoid P
1	126.2	25.36	22.98	3.59
2	113.4	22.03	20.20	4.47
3	128.0	30.08	27.26	4.20
4	123.4	25.23	22.96	3.94
Average	122.9	25.68	23.35	4.05

TABLE VI  
*Concentration of Creatine*  
 (In mg per 100 c.c. of Milk)

Expt	Creatinine	Creatine	Creatine phosphorus acid
1	0.734	1.267	2.073
2	0.629	1.206	1.942
3	0.593	1.324	2.132
4	0.746	1.543	2.485
5	0.483	1.704	2.744
6	0.599	1.654	2.663

In order to see the average variation in the composition of milk several samples were examined. Analyses of some of the samples are given in Tables I and II. These variations however do not affect our results of the detailed analyses of milk, as the relative amounts of phosphorus compounds do not change (*vide* Table III).

Table IV gives the different types of compounds of phosphorus in mg per 100 c.c. of milk. It will be seen that 73.6 per cent of the total phosphorus in the whole milk is soluble in trichloracetic acid, which is in agreement with that obtained by Graham and Kay (*loc. cit.*).

In the acid-soluble portion of milk Graham and Kay have found 65.2 per cent of the total phosphorus in the inorganic form and 9.8 per cent as organic, which they call esters. From our method, the results of which are given in Tables III and IV, it is seen that only 50.24 per cent (ortho + pyro) of phosphorus constitutes inorganic variety and as much as 24.27 per cent is in the organic form. The lower value for the inorganic variety was expected as the easily hydrolysable organic phosphorus compounds in Fraction B were separated from the inorganic by adjusting the acid extract of milk to a pH 9 with baryta. A study of the nature of this variety accounts for the incorrect values obtained by Graham and Kay.

*Fraction B*—The phosphorus in Fraction B exists in two forms (1) directly estimable by Brigg's method and (2) obtained after oxidation and hydrolysis. The former constitutes 9.1 per cent and the latter 4.8 per cent of total phosphorus (*vide* Tables III and IV).

The easily hydrolysable phosphorus changes into ortho condition of Fraction A, in presence of trichloracetic acid, on heating or on dialysing the milk. This organic variety is, therefore, mistaken for the inorganic type.

In order to find the nature of these organic phosphorus compounds various substances were looked for. But, except for creatine and lactose, the identity of other substances could not be established. Creatine in milk was estimated according to Masayoshi Sato and Kuchi Murata.<sup>9</sup> The amount of creatine found in milk is given in Table VI, column 2. It is likely that creatine might exist as creatine phosphoric acid which is hydrolysed by acid. This creatine phosphorus unlike in the case of muscle (Eggleton, *loc. cit.*) accounts only for a part of the hydrolysable variety. Therefore some other substance may be associated with this organic phosphorus.

It is not clear in what form lactose exists in milk. It has been suggested by Mai Monatsschr.<sup>10</sup> that lactose is bound up with phosphorus in loose combination. If so only a very small amount of lactose present in milk will be used in this combination. This point requires further investigation.

*Fraction A*—In Tables III and IV are given the amounts of the compounds of phosphorus, insoluble at pH 9 in presence of barium hydroxide. It will be seen that this fraction is divided into three types

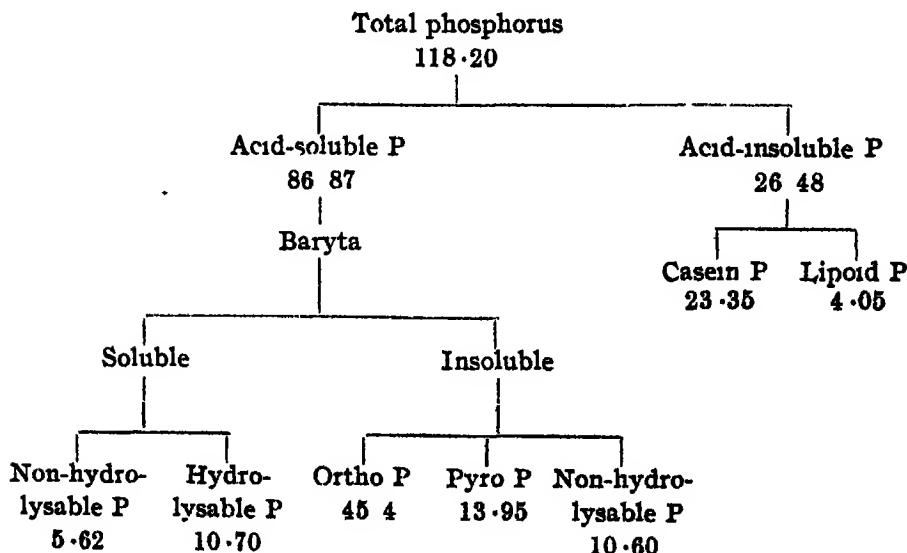
<sup>9</sup> *J. Agri. Chem., Soc. Japan*, 1933, 9, 1-5.

<sup>10</sup> *Kinderhelsk*, 1932, 51, 391-92.

ortho, pyro and non-hydrolysable phosphorus From Table IV, column 5, it is seen that 38.42 per cent of the total phosphorus is in the ortho- and 11.8 per cent in the pyro-condition The non-hydrolysable variety forms 9.1 per cent of the total phosphorus

The amount of phosphorus in the acid-insoluble portion of milk is given in Table IV, column 3 It may be noted that 22.4 per cent of the total phosphorus, which is present in the acid-insoluble portion, consists of lipoid phosphorus 3.7 per cent, and casein phosphorus, 19 per cent (refer Table V)

It will be seen thus from the above discussion that we have been able to establish the existence of five independent types of phosphorus compounds ortho, pyro, organic phosphorus compounds insoluble in barium hydroxide at pH 9 and hydrolysable and non-hydrolysable organic phosphorus compounds soluble at pH 9, over and above these the acid-insoluble phosphorus consists of casein phosphorus and lipoid phosphorus. The amount of phosphorus present in these seven varieties are estimated directly, as shown below in mg per 100 c.c. milk —



## PHOSPHORUS, CALCIUM AND MAGNESIUM IN MILK-II

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CALCIUM, magnesium and phosphorus are capable of forming both soluble and insoluble salts, but the mode of formation of the latter will be of great interest. Some workers have drawn their conclusions regarding the salt formation in milk from the analysis of the scum formed after heating the milk, others generalised merely on the strength of their experiments of dialysis or of ultra-centrifuging and so on.

Van Slyke and Bosworth<sup>1</sup> have shown that milk contains  $\text{CaHPO}_4$  on the results of their ultra-centrifuge experiments.

Soldner and others<sup>2</sup> have found that on heating milk a scum is deposited which is mostly tricalcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$ , concluding its presence originally in milk.

Palmer<sup>3</sup> however thinks that  $\text{CaHPO}_4$ , stabilised with gelatine, forms a precipitate of colloidal calcium phosphate on heating.

Various workers<sup>4</sup> have studied the effect of dialysis of milk and tried to draw inferences about the composition of salts in milk which do not seem to be definite. Considerable divergence in their observations is to be attributed to the fact that the experimental conditions were different in each case.

**Casein**—a phospho-protein body in milk was also subjected to various experiments. Somer and Hart<sup>5</sup> state that casein forms some kind of loose

<sup>1</sup> *J. Biol. Chem.*, 1915, 20, 135, 1916, 24, 199

<sup>2</sup> Soldner, *Landw. Versuches Stat.*, 1885, 35, 351; de Vries and Boekhout, *Ibid.*, 1901, 55, 201; Purvis, Brehat and M'Hattie, *J Roy San Inst.*, 1912, 33, 154; Grosser, *Biochem. Z.*, 1913, 42, 422, Difflith, *Bull Soc Pharmacol.*, 1904, 10, 278

<sup>3</sup> *Proc Soc Exp. Biol. Med.*, 1921

<sup>4</sup> Gyorgy, *Biochem. Z.*, 1928, 142, 1, Mattick and Hallett, *J Agric Sci.*, 1929, 19, 452; Wardlaw, *J. Roy. Soc., N.S.W.*, 1914, 48, 253, etc

<sup>5</sup> *J. Biol. Chem.*, 1919, 40, 187

compound with calcium. It is reported that casein on suspension in water, or on heating for some time, loses some of its phosphorus.<sup>6</sup> Berggren<sup>7</sup> is of opinion that the phosphorus of casein is more loosely bound than is usually supposed.

To get an insight into the distribution of calcium, magnesium and phosphorus in milk the problem of the composition of milk is to be approached in several ways. In the present investigation estimations of phosphorus, calcium and magnesium were made under varying conditions. First of all milk was divided into two portions soluble and insoluble in trichloracetic acid (2 c.c. of 25% acid for 0.5 c.c. of milk diluted to 3 c.c. with water). Next the amounts of the constituents of whole milk which are dialysable were differentiated from the undialysable. Lastly fresh milk was heated after removing the fat, till scum was formed. The scum was analysed. The residual milk free from scum was divided into two portions—soluble and insoluble—in trichloracetic acid.

For the estimation of phosphorus Brigg's method was used. For calcium, the method of Masayoshi Sato and Kuchi Murata<sup>8</sup> with a few modifications was adopted. Magnesium was estimated by the usual gravimetric method.

#### *Results and Discussions*

TABLE I

#### *Amount of Total, Acid-Soluble and Acid-Insoluble Phosphorus, Calcium and Magnesium*

(In mg per 100 c.c. of Milk)

No	1			2			3		
	Total			Acid Soluble			Acid Insoluble		
	P	Ca	Mg	P	Ca	Mg	P	Ca	Mg
1	120.2	148.2	18.42	100.30	99.26	17.23	25.36	48.00	1.19
2	113.4	146.3	14.31	92.36	98.24	13.30	22.03	48.28	1.01
3	128.6	152.4	19.03	97.10	101.34	18.31	30.08	50.48	1.32
4	123.4	149.2	18.83	96.50	98.34	17.52	25.23	50.50	1.31
	122.95	149.0	18.00	96.57	99.30	16.59	25.68	49.32	1.21

<sup>6</sup> Loubavin, *Ber.*, 1877, 10, 2237, 1879, 12, 1021

<sup>7</sup> *J. Biol. Chem.*, 1922, 95, 451

<sup>8</sup> *J. Agr. Chem. Soc. Japan*, 1933, 334-36

TABLE II

*Analysis of the Scum and the Milk after removal of Scum*

(In mg per 100 c.c. of Milk)

	1			2			3		
	Total			Acid Soluble			Acid-Insoluble		
	P	Ca	Mg	P	Ca	Mg	P	Ca	Mg
Whole milk	126.4	148.20	18.42	100.30	99.26	17.23	25.36	48.00	1.89
Milk heated and scum removed	99.64	86.20	10.10	78.64	71.63	9.60	21.06	15.60	0.50
Scum	27.40	64.00	8.00						

Scum is derived from the acid soluble and acid insoluble fractions

TABLE III

*Amounts of Dialysable and Undialysable Phosphorus, Calcium and Magnesium*

(In mg per 100 c.c. of Milk)

Time in hours	I			II			III		
	Total			Dialysable			Undialysable		
	P	Ca	Mg	P	Ca	Mg	P	Ca	Mg
0	126.4	148.2	18.42						
6				43.20	44.32	10.42	82.68	102.94	8.00
12				47.63	48.06	12.39	77.35	99.83	6.03
18				53.93	53.58	14.00	71.96	94.63	4.42
24				60.32	60.00	16.10	64.90	98.32	2.32
30				60.32	60.20	16.32	63.19	86.28	2.10

The above results show that even before twenty four hours all the (maximum) dialysable constituents have passed out in the dialysate

TABLE IV

*Amounts of Dialysable and Undialysable Phosphorus, Calcium and Magnesium*

(In mg per 100 c.c. of Milk)

*(Results of 30 hours Dialysis of the same Four Samples of Milk used in Table I, respectively)*

1				2			3			4		
DIALYSABLE				UNDIALYSABLE			UNDIALYSABLE ACID SOLUBLE			UNDIALYSABLE ACID INSOLUBLE		
No.	P	Ca	Mg	P	Ca	Mg	P	Ca	Mg	P	Ca	Mg
1	62.23	60.20	16.32	63.13	86.28	2.10	43.86	51.48	1.02	14.20	33.46	Traces
2	52.90	56.30	12.23	59.17	89.10	2.08	46.38	47.96	1.07	12.20	40.34	..
3	62.40	60.40	16.86	65.32	91.60	2.77	48.20	50.56	1.16	16.87	40.83	..
4	55.35	55.10	15.93	66.94	82.40	2.00	47.86	49.26	1.20	18.80	32.82	,
	58.32	68.00	15.36	63.65	87.35	2.46	47.83	49.82	1.11	15.52	36.86	

*N.B.—Sum of 1 and 3 is more than the acid soluble of column 2 in Table I. For explanation see text.*

*Similarly 4, acid insoluble contents on dialysis are less than that in column 3, Table I.*

TABLE V

*Analysis of Milk Dialysed for 6 and 30 Hours (Undialysed Acid-Soluble and Insoluble Fractions) Concentration of Phosphorus, Calcium and Magnesium*

(In mg per 100 c.c. of Milk)

Casein in gm	1	2			3			4		
	TOTAL	ACID SOLUBLE			ACID INSOLUBLE					
		F	Ca	Mg	P	Ca	Mg	P	Ca	Mg
Whole milk	3.2	126.4	148.2	18.42	100.30	99.26	17.23	25.36	48.00	1.19
Milk dialysed for 6 hrs	2.9	78.46	103.04		61.00	63.00		16.86	40.14	.
Dialysate after 6 hrs		44.46	44.62	10.42		.				
Milk dialysed for 30 hrs		63.13	86.28	2.10	48.86	51.48	1.20	14.13	33.46	.
Dialysate		62.23	60.20	16.32	.					

*N.B.—In Tables II, III and V, the values obtained in the case of an experiment, i.e., one sample of milk are given. The process of heating and dialysis being semi-quantitative, the other three sets of readings obtained are not identical with these values as it is to be expected, but are similar to them and lead to the same conclusions. They are not reproduced here.*

TABLE VI

*Amount of Phosphorus in the Undialysable Acid-Soluble Fraction*  
 (In mg per 100 c.c. of Milk)  
*As Tricalcium and Magnesium Phosphate*

Expt	<i>a</i> Free phosphorus, as undialysable acid soluble phosphorus	<i>b</i>		<i>a - b = c</i> Phosphorus in organic com pounds
		Phosphorus as $\text{Ca}_3(\text{PO}_4)_2$	Phosphorus as $\text{Mg}_3(\text{PO}_4)_2$	
1	48.88	26.61	1.030	21.22
2	49.38	24.77	0.922	21.56
3	48.20	26.12	0.900	21.08
4	47.88	25.45	1.030	21.38

1 *Acid-insoluble Phosphorus, Calcium and Magnesium*—The amounts of phosphorus, calcium and magnesium in milk, acid-soluble, and acid-insoluble fractions are recorded in Table I. It can be seen that the amounts of acid-insoluble phosphorus, calcium and magnesium are 25.68 mg., 49.32 mg and 1.21 mg respectively. It is clear that the concentration of the acid, or more accurately pH of the resulting solution is such that all the calcium and the magnesium salts such as carbonates, phosphates, etc., must be soluble. The only source of phosphorus, calcium and magnesium must be, therefore, from those substances which are precipitated by the acid, i.e., the proteins mainly casein (lactoalbumin and lactoglobulin). It has been shown that the acid-insoluble phosphorus consists of casein phosphorus *plus* lipid phosphorus.\*

The next question is to trace the source of calcium and magnesium. It is suggested that calcium must be in the form of a loose compound like calcium caseinate.<sup>10</sup> But if we look at the molecular proportions of calcium and magnesium and that of casein, no direct relationship is apparent. A more plausible explanation, however, appears to be the adsorption of the calcium and the magnesium ions by casein complex molecules, to form a colloid system and that the acid coagulates this colloid and the ions of calcium and magnesium are adsorbed by the coagulum.

\* Acharya and Devadatta, Proc. Ind. Acad. Sci., same volume.

<sup>10</sup> Van Slyke and Bosworth, J. Biol. Chem., 1915, 20, 135; 1916, 24, 199.

**2 Scum of the Milk**—Fresh Milk on mere heating gives rise to a scum which when dry has the following composition—Phosphorus 27.4 mg., Calcium 64.00 mg., and Magnesium 8.00 mg. per 100 c.c. of milk (refer Table II) The explanation of this scum formation is (1) the coagulation of some constituents which are dispersed colloidally and (2) the formation of insoluble salts—both as a result of heating. The former phenomenon is evident and needs no comment. If this scum was derived exclusively from the colloidally dispersed constituents, we should expect that the acid-insoluble portion of milk, free from scum on analysis, should show a decrease, corresponding to the amounts of phosphorus, calcium and magnesium found in the scum, but it should not affect these in that portion of milk which is acid-soluble. It is observed that there is a decrease in the acid-soluble constituents also. Some colloidal substances like calcium and magnesium phosphates have been coagulated. There is also the precipitation of acid phosphates, and carbonates of calcium and magnesium, which before heating, in the form of acid salts, are more soluble in water than the normal salts. On heating milk for a long time in presence of few drops of methyl orange, a decrease of acidity was observed.

**3 Water-soluble and Water-insoluble Constituents**—It is seen from Table I that the amounts of phosphorus, calcium and magnesium that are soluble in acid are respectively 96.67 mg., 99.30 mg., and 16.59 mg. per 100 c.c. of milk. Milk may contain calcium and magnesium as carbonates, phosphates, lactates, etc., both in the form of normal salts and of acid salts. To estimate the amounts of acid salts—soluble in water, milk was dialysed for 30 hours against distilled water, and the dialysate was analysed. In Table IV are given the amounts of dialysable and undialysable phosphorus, calcium, magnesium, in mg. for 100 c.c. of milk, i.e., soluble salts P = 58.32, Ca = 58.00 and Mg = 15.36 mg., and insoluble salts P = 63.65, Ca = 87.35 and Mg = 2.46 mg.

For a particular sample shown in Table V it can be seen that the amounts of phosphorus, calcium and magnesium that pass out of the bag during dialysis for six hours are, 44.46 mg., 44.62 mg. and 10.42 mg. respectively. The constituents which are not dialysable but soluble in acid are—phosphorus 61.00 mg., calcium 63.00 mg. and magnesium only traces. Similar values are given for 30 hours dialysis. On comparing the total of dialysable and acid-soluble undialysed constituents, Table IV, columns 1 and 3, with the total acid-soluble constituents, Table I, column 2, there is an increase in the amounts of phosphorus, calcium and magnesium present in the acid-soluble (dialysable *plus* acid-soluble undialysable) portion, on dialysis. It may be noted also that there is a corresponding

decrease in the acid-insoluble portion (undialysable) The increase in the amounts of acid-soluble constituents of phosphorus, calcium and magnesium amounts to 9.73, 8.52, and 1.11 mg respectively, on dialysing milk for 30 hours (Table V) This is due to the fact that casein, which had adsorbed calcium and magnesium ions, on coming in contact with water becomes partly soluble, otherwise quite insoluble in acid Further, it can be seen that casein decreases in undialysable milk from 3.2 to 2.9 gm per cent It is also possible to detect some casein in the dialysate Therefore our assumption that the acid-insoluble phosphorus, calcium and magnesium as being associated with casein is corroborated (*vide* below)\*

4 *Acid-soluble Phosphorus, Calcium and Magnesium*—The insoluble or undialysable fraction is further subdivided into acid-soluble and acid-insoluble parts From Table IV, column 3, it will be seen that the amounts of phosphorus, calcium and magnesium which are soluble in acid but insoluble in water are as follows phosphorus 47.83 mg, calcium 49.82 mg and magnesium 1.11 mg per 100 c.c. of milk (cf Table V) These amounts refer to such salts as tricalcium and magnesium phosphates If we look to the amounts of phosphorus we find that it is much more than what should correspond to tricalcium and magnesium phosphates as noted in Table VI That surplus phosphorus may be the portion of phosphorus combined to the acid-soluble organic phosphorus discussed elsewhere\*

#### *Summary and Conclusions*

In conclusion, it may be said that the portion of milk insoluble in acid is mostly casein which had adsorbed some ions of calcium and magnesium The portion soluble in acid but insoluble in water consists of tricalcium and magnesium phosphates and organic phosphorus Scum which is collected after heating the milk is derived both from the acid-insoluble and from the acid-soluble portions On dialysis some acid-insoluble portion becomes water soluble The water-soluble portion of milk consists of acid phosphates of calcium and magnesium The amounts of phosphorus, calcium and magnesium present in water, acid-soluble and insoluble fractions—and in scum of 100 c.c. of milk are recorded

We are grateful to Mr P M Barve for his helpful suggestions



# STUDIES IN SORGHUM SUDANENSE, STAPF—THE SUDAN GRASS

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## *Introduction*

SUDAN GRASS is a Grass Sorghum introduced into America from the Sudan. Its importance is because of its high forage value in America and also in other parts of the world. *S sudanense* belongs to the series *Spontanea*, sub-section *Arundinacea*, in the *Eu-sorghum* section of the genus *Sorghum*.<sup>1</sup> Snowden after an intensive examination of several sorghums, both wild and cultivated, comes to the conclusion that the cultivated sorghums belonging to the sub-series *Bicoloria* in the series *Sativa* (also of sub-section *Arundinacea*) are the products of some combination of *S ethiopicum* (Hack) Rupr ex Stapf and *S sudanense*, Stapf. He thinks it probable that in view of the close affinities, *S dochna* (of the sub-series *Bicoloria*) owes its origin very largely to *S sudanense*.

The reasons for this probable contribution of *S sudanense* to the origin of some races of cultivated sorghum are (1) its ready crossing with cultivated sorghums and the large number of grain sorghum natural crosses that occur in it, (2) its tough racemes, (3) the persistent pedicelled spikelets,<sup>2</sup> (4) the absence of deciduousness of sessile spikelets through callus formation,<sup>3</sup> (5) size and shape of sessile spikelets, (6) the arrangement of the spikelets in the panicle, (7) time of anthesis,<sup>4</sup> and (8) absence of hard seeds.

The studies presented in this paper represent experiences gained in the course of the examination of crops raised from fifty seed samples from various sources, including forty from Russia, during the last five years.

## *Agro-Botanical Description*

*Duration*—80 to 110 days, *Seedlings*—coleoptile deep purple, purple, or green<sup>5</sup>; *Seedling-leaves*—bluish green or green<sup>6</sup>, *Leaf-sheath*—blackish-purple<sup>7</sup>, *Nodal band*—purple, *Stray cases* green<sup>8</sup>, *Axil of leaf-sheath above*

*nodal band*—purple, stray cases green, *Auricular junction*—purple, stray cases green, *Midrib*—white<sup>9</sup>, *Awn*—long 9 to 11 mm, stray cases nil; *Stigma*—very light yellow, *Anther*—(fresh), very light yellow, (dry) very light brown<sup>10</sup>, *Grain*—brown in colour, enclosed in glumes, *Glume*—bleached blackish purple, stray cases unbleached, *Panicle*—loose conical, secondary branches adpressed (occasionally diverging), tertiary branches absent in some cases, *Spikelets*—arranged in a cymose fashion, *Emergence*—good, about 15 cm, *Peduncle*—about 40 cm long, hollow just immediately below the panicle, *Tillers*—15 to 20, the main and primary tillers (almost contemporary to it) are both unimodal in internodal disposition, the late tillers arising from the primary tillers are however of the uniform increasing type<sup>11</sup>, *Bloom*—very sparse, stray cases apparently nil<sup>12</sup>

The studies on this Sudan grass could be grouped into (1) rare characters that are common to *S. sudanense* and *S. dochna* (more a fodder than a grain sorghum), (2) characters experienced so far in Sudan grass only, and (3) those that are of evolutionary interest

#### Rare Characters that are Common to *S. sudanense* and *S. dochna*—

*E-ligulate and Non-auriculate Condition of the Leaves*—In a previous publication it has been recorded that the *e-ligulate* and non-auriculate condition in Sudan grass (gene *lg*) is a simple recessive to the ligulate and auriculate condition<sup>13</sup> (*Lg*). In many of the extracted types of Sudan grass from Russia an *e-ligulate* condition prevails. When it occurs, the plant assumes an erect habit and looks compact and rigid (Fig 1) and the earheads are rod-like. As in cultivated sorghums, in Sudan grass also, when the ligule and auricle are absent, the pulvinus is absent (Fig 3) and there is a shortening in the spikelet-free area in the base of panicle branches and branchlets<sup>14</sup>. This leads to a compact head with panicle branches overcrowded with spikelets. The contrast between a loose head from a ligulate and auriculate plant and a compact head from an *e-ligulate* non-auriculate plant, is well brought out in Fig 2. The occurrence of the *e-ligulate* condition has been recorded in *S. sudanense* and in Broom corn (*S. dochna* var *technicum*). This concurrent manifestation of the same rare character in both these sorghums is very significant in the support that it gives about the contribution of *S. sudanense* to the evolution of *S. dochna*.

*Compact-spindle Panicle*—Being a 'wild' sorghum the panicle in Sudan grass is usually loose and conical. A rare heterozygous mutation was met with in family No S 75 (Guntur collection) in which there occurred a segregation for panicle shape only, giving 161 plants with loose conical

panicles and 48 with compact spindle-shaped ones. The unusual occurrence of this compact spindle (not the compactness associated with the E-ligulate condition) in this grass is significant. This type of panicle ( $Pa_1$ ) has been reported upon in *S. dochna*<sup>16</sup>. This lends a second evidence to its affinity to *S. dochna*.

*Pedicelled Spikelets with a Wash of Purple*—The pedicelled spikelets in sorghum are usually unpigmented. They are green when fresh and straw-coloured when dry. In red-grained sorghums where the sap colour invades even the pedicelled spikelets, a tap of the ripe head will dislodge a number of red coloured pedicelled spikelets. This is one of the characters in the sap colour series associated with red-coloured grains.<sup>8</sup> In the case of the P and Q factor manifestations of purple pigments, i.e., reddish-purple and blackish-purple of leaf-sheath and glume,<sup>7</sup> the pigment never shows well on the glumes of pedicelled spikelets. There is another type of manifestation of purple pigment which is related to P and Q and which shows in certain African varieties only, even on the emergence of the panicle from the boot.<sup>17</sup>

In most of the Sudan grasses a new type of manifestation of purple pigment (not of the P type) is met with. It is the presence of this type of pigment that gives the characteristic purple-washed appearance to a fresh panicle beginning to flower. The purple-wash is seen on the first glume of the pedicelled spikelet which is the one that is most exposed to the sun. When so exposed, the second glume is also coloured. The colour is deeper at the base of the glume and is best seen at flowering time, but it disappears at about the dough stage of the grain. This special manifestation of purple pigment is peculiar to Sudan grass. A gene designated PW is responsible for the manifestation of the purple pigment mostly on the exposed first glume of the pedicelled spikelet in Sudan grass. In the F<sub>2</sub> of family No S 75 (Guntur collection) there was a 3:1 segregation with 154 purple-washed spikelets and 58 green spikelets. It is interesting to note that this additional purple dominant gene which has dropped out in most of the cultivated sorghums<sup>17, 18, 19</sup> has been met with in Africa, an additional evidence of its being the home of sorghum. This character was also met with in certain varieties of *S. dochna* from China. The occurrence of this phenomenon in *S. dochna* is an additional and third evidence for the probability of *S. sudanense* being a progenitor of the *S. dochna* group of cultivated sorghums.

#### *Characters Experienced in Sudan Grass Only—*

*Banded-seedlings*—Seedlings with chlorophyll deficient bands have occurred in Sudan grass (Guntur collection). The bands are prominent in

the broad first seedling-leaf<sup>20</sup> They are white and are devoid of chlorophyll The band may be at the tip, top, middle or at the sides of the first seedling leaf It is usually in a single and occasionally in more than one band The bands are 1 to 2 mm wide They may show in the second seedling leaf also This character expresses in seedling-leaves only In stray cases the lower leaves in a tiller have repeated this experience The adult plants do not give a clue to this character In crosses between banded and normal varieties, the normal green condition proved a simple dominant character The F<sub>1</sub> segregation gave 317 non-banded seedlings and 100 banded seedlings. A gene designated cb is responsible for inducing albinotic bands in the seedling leaves of Sudan grass

*Seedling Habit*—A study of seedlings in seed-pans shows that sorghum seedlings differ in habit These differences are minute in grain sorghums In Sudan grass with its characteristic tillering, seedling habit differences have however been perpetuated graphically There are pure lines in which the seedlings have a spread-out habit, the tillers making an angle of about 45° with ground level There are other pure lines in which the tillers are practically erect This seedling habit is best seen when the seedlings are about 4 to 5 weeks old It gets obscure on and after flowering In crosses between the two types (Guntur collection) the open habit has proved a simple dominant to the erect habit In the F<sub>1</sub> generation (family No S 86) 86 open and 30 erect seedlings were obtained A gene designated SO produces seedlings with an open habit

*Striping of Leaves*—Regular striping in leaves is often pathological in origin<sup>21</sup> Irregular and erratic stripes are aspects of maternal inheritance<sup>22</sup> True breeding types with faint and regular white longitudinal stripes on the leaf-blades have been recorded by Russian workers<sup>23</sup> They note that such plants were weak Unlike their experience, which was probably due to poor populations good monogenic segregations have been obtained between normal green and striped leaves, the figures from three segregating selections from family No S 173 from Russia being 130 and 32, 200 and 65, and 125 and 40 respectively A gene designated cs produces leaf-blades with thin white stripes It is interesting to record the fact that when the leaves are striped, a few glumes exhibit a similar striping

*Bloom*—In a previous paper the occurrence and inheritance of waxy bloom has been recorded<sup>11</sup> Heavy bloom is a simple dominant to sparse bloom It was then stated that the wild sorghum group in which was included *S. sudanense* shows a distribution of bloom that is more sparse than in the grain sorghums The examination of many lines of Sudan grass

shows that, whereas the bloom is very sparse in the majority of types, there occur types in the Guntur collection with a still sparser manifestation of bloom, bordering on absence. On the leaf-sheath (especially on the boot at flowering time) and on the internode, the normal Sudan grass has a very sparse coating of bloom. In the extremely sparse bloom condition, the internode is practically bloomless while the boot retains traces of bloom. Segregations have been obtained for the very sparse and extremely sparse condition of bloom, the total of five families in both  $F_2$  and  $F_3$  being 219 very sparse to 70 extremely sparse. Another dilution gene seems to determine the lightness of manifestation of the bloomy condition. The relationship of the four types is being worked out.

*Panicle*—In this grass the primary branches of the panicle have pulvini and make an angle with the central stalk. The secondary branches lack the pulvini and are therefore practically adpressed to the primary branches. Whereas the majority of Sudan grasses have such adpressed secondary branches, there were found two pure lines one from Russia and another from Guntur in which the secondary branches had well marked pulvini resulting in their being at about a right angle to the primary branches giving the earhead a fulness in look in contrast to the sketchy appearance of the usual type (Fig. 4). In crosses between the two types, the angular condition of the secondary branches has proved a simple dominant to the adpressed condition. In the  $F_2$  generation a monogenic segregation of 49 angular to 17 adpressed plants was obtained. This behaviour was in a loose conical type ( $Pa_1$ ), in which the primary branches with their marked pulvini ramified from the central stalk and made it easy to pursue this character. The sparse-headed 'wild' sorghum has thus given a helpful clue to one of the constituents in panicle structure. A gene designated  $Pa_2$  thus determines the angular disposition of the secondary branches to the primary branch. In grain sorghums that are more highly evolved, other factors like compactness of the panicle and heaviness of the grain make it difficult to pursue easily the effect of this gene.

Another contribution that this 'wild' Sudan grass has to make to the understanding of panicle structure, is the light that it throws on the arrangement of the spikelets on the panicle. The sessile and pedicelled spikelets are arranged in the form of a cyme. All the sessile spikelets represent the main flower of the cyme and the pedicelled spikelets the lateral ones. The whole arrangement is dichasial but with an alternate development (Fig. 8). This explains why every sessile spikelet has a pedicelled one and the terminal sessile spikelet two pedicelled spikelets, one of which the ultimate,

has always a slightly longer pedicel than that of its mate All the sorghums, whether wild or cultivated examined so far conform to the above description In the cultivated sorghums this is not quite clear owing to the over-crowding of the spikelets In a cyme the middle flower is the oldest and flowers first This fact explains the second wave of anthesis of the pedicelled spikelets in the cultivated sorghums which has been described in great detail in a previous paper<sup>24</sup>

A proliferated earhead occurred in family S 52, a Sudan grass pure line from Guntur (Fig 5) In this the lower panicle branches turned into vegetative shoots and thus evidenced the evolution of the panicle from foliar organs It is noteworthy that some of the vegetative shoots however give out panicles once again from some of their axils

#### *Characters of Evolutionary Interest—*

**Tillering**—The tillering habit is an important attribute of the Gramineae A tussock is a product of heavy tillering In the evolution of the cereals with their definite sowing and harvest time, a fairly uniform maturity of earheads is a requisite Under crowded conditions, cereals can be few headed, provided they are fairly uniform in duration In sorghum a practically single stalked condition has been bred up from a many tillered condition by not giving full scope for the tiller buds to develop Although tillering is affected by spacing, the capacity of sorghum varieties to tiller varies with varieties Among the cultivated varieties, *S durra* is normally non-tillering and Feterita belonging to *S caudatum* is usually a tillering variety Tillering connotes wild vigour and non-tillering condition is brought about by cultural and selective operations, until the whole plant puts forth its undeviated vigour into the production of one large earhead The following experiences met with in Sudan grass help in understanding this valuable attribute of grasses, viz., tillering

Among the many *pure* lines of Sudan grass that are being grown at the Millets Breeding Station, S 77 is one belonging to the collection from Guntur This was true to the tillering habit in 1935 In 1936 the single plant selection carried forward from the 1935 crop, instead of coming pure as expected, segregated throwing out a few strange plants, anaemic, tillerless and absolutely single stalked (Fig 7) There were 78 plants with tillers like the parent and 20 of the strange weak group It was obvious that there had occurred a mutation heterozygous in nature From this *F<sub>1</sub>*, an *F<sub>2</sub>* generation was raised and the behaviour of the selections is given below

TABLE

Selection Number	Character of the F <sub>1</sub> Selection	F <sub>2</sub> Behaviour	
		Tillering	Single-stalked
S 103	Single-stalked	.	Pure
S 105	Tillering	Pure	.
S 103	"	Pure	
S 104	"	49	14
S 106	"	70	26
S 107	"	96	12
S 109	"	134	18
TOTAL .		349	120
Calculated 3 : 1		351 75	117 25

$$\chi^2 = 0.086 \quad P > 7$$

It will be noted that 4 of the 6 tillering plants were heterozygous and segregated again. It is clear that the tillering habit is a monogenic dominant to the absolutely single-stalked non-tillering condition which has been met with for the first time in this sorghum. Out of the 120 single-stalked plants only 8 survived till maturity, the rest succumbing to the attack of the shoot borer. In the pure line S 103, out of the 17 seedlings that germinated only one reached the stage of maturity. Being weak, the main shoot dying, and unable to produce tillers (basal buds absent), these anemic plants are of very poor survival value. Before discussing this phenomenon, the contrasting characters in the two groups, viz., tillering and absolutely single-stalked, are given below —

Character	Tillering plants	Single-stalked plants
Tillers	12 to 15	Nil (basal buds absent)
Vigour	Healthy	Sickly
Seed setting	Good	Poor (10 to 15%)
Faniole—		
Shape	Loose and conical	Compressed and rod like (Fig 8)
Top	Normal	Ending in a spur
Number of whorls	16 to 18	10 to 12
Pulvinus	Present	Absent
Primary branches	About 53° to the axis	Adpressed to the axis
Spikelets and their distribution	Many, evenly distributed	Few, crowded at tips of branches (Fig 9)
Sessile spikelets—		
Number	1000 to 1200	Less than 200
Size	6.0 × 2.75 mm	7.25 × 2.25 mm
Sessile spikelets—		
Nature	Coriaceous and short nerved	Papery and long nerved
Length of nerves on glumes	2.5 mm	5.5 mm
Pedicelled spikelets—		
Number	1300 to 1500	Less than 50
Size	5.0 × 1.25 mm.	More scales or absent
Length of pedicel	2.0 mm	Do
Flowering	Ordinary	Partly cleistogamous

All these connote a primitiveness of equipment in the single stalked plant that has naturally not helped in the survival of this type in nature. The ready susceptibility to attack from the seedling-borer and the poor setting of seed make it difficult to perpetuate the single-stalked pure line.

With the help of this experience it has now become possible to give a genic background to this common phenomenon of tillering. A gene designated TX is at the back of the tillering habit in *S. sudanense*. Gene tx gives rise to an absolutely single-stalked (tiller-less) plant. The capacity to produce tillers is absent through the absence of buds at ground level. This is different from the single stalk of the grain sorghum in which the buds are present and could be activated. The higher axillary

leaf-buds could however be stimulated into activity, but since the frame of the plant is so frail this potentiality leads to no fruitful result. The spur that plumes the panicle seems to be the long central axis prolonged. The tillering habit, short coriaceous glumes, short nerves on these and the presence of pedicelled spikelets—attributes of modern sorghums—show the great advance in their evolution.

Whereas the above experience chronicles a case of tiller *versus* no tiller, Sudan grass has afforded a second interesting experience in the nature of advance in the tillering habit. Among the pure lines of Sudan grass there exist two distinct tillering types. The majority of pure lines have the first shoot well ahead of the later straggling tillers. In a few types the tillers flower practically along with the main stalk. At the flowering time the two types are very readily distinguishable, the latter being weak. In crosses between these two types the comparatively un-uniform flowering type proved a simple dominant to the dead uniform flowering type. In family No S 200, also from Guntur, there occurred a segregation giving 64 plants with tillers maturing much later than the main head and 22 plants with tillers maturing almost with the main head. The latter are shorter, their stalks are thinner, and the panicles are smaller, and there are no late tillers. It looks therefore that the lack of vigour in this group has been brought about by the over rapid activation of buds and the unspaced development of tillers arising from such activation.

A gene TU seems to be responsible for a gradual activation and delayed and spaced growth of tillers in Sudan grass. Gene tu gives rise to a uniform activation, uniform growth and maturity and consequent weakness of the tillers and the plant in general. These experiences in the tillering habit of Sudan grass are valuable in giving a clue to the fact that behind the vigorous tillering and the suppression of such tillers resulting in the single-stalked condition of Sorghum—the Great Millet—there exist genetic factors whose detection is difficult, under the obscuring effects of continued cultivation.

**Weak Midrib**—Another phenomenon of great evolutionary interest is the weak midrib. In a family raised from selection S 92 received from Trivandrum, which must have been a mutant (heterozygous), there occurred a number of plants very abnormal in appearance. In them, instead of the characteristic rigid leaves, the leaves were ribbon-like, weak, supple and bent down. Counts taken showed that there were 36 normal plants with a normal midrib in the leaves and 10 plants with a weak midrib. The weak-midrib-plants had many disabilities with the result that they did not produce

any seed. The occurrence of this rare character necessitated a large number of selections being carried forward to the third generation. Out of the 36 normal plants available, except the two that were very poor, all the others were carried forward and a third generation raised. Of the 34 selections, 11 were pure for normal plants and 23 segregated repeating the F<sub>2</sub> experience. The figures are given below —

TABLE  
F<sub>3</sub> from S 92 Family

Selection Number	Character of Selection	F <sub>3</sub> Behaviour Midrib	
		Normal	Weak
S 118	Normal Midrib	27	9
119	"	24	9
120	"	70	22
121	"	46	13
122	"	119	34
123	"	50	17
124	"	59	23
125	"	106	33
126	"	174	54
128	"	57	19
131	"	153	52
132	"	67	22
133	"	172	55
134	"	17	4
135	"	85	28

Selection Number	Character of Selection	$F_2$ Behaviour Midrib	
		Normal	Weak
S 136	Normal Midrib	141	50
137	"	107	34
138	"	42	11
141	"	41	13
142	"	33	11
144	"	74	26
147	"	69	29
149	"	122	46
	TOTAL	1855	614
	Calculated 3 1	1851 75	617 25

$$\chi^2 = 0.023 \quad P < .8$$

A gene designated MD is responsible for producing a strong and normal midrib in the leaf-blade of sorghum. Gene md results in a weak midrib, which is the cause of the ribbon-like leaf-blades that lack erectness (Fig. 10).

Among the families which segregated and gave the weak-midrib there was also a segregation for the bluish-green\* and green colour of (seedling) leaves in 14 of them. The cross-collated tabulation given below shows that the factor MD is independent of the factor C<sub>BL</sub>.

TABLE

Selection Number	Strong Midrib		Weak Midrib	
	Bluish-green	Green	Bluish-green	Green
S 118	19	8	8	1
119	17	7	6	3
120	53	17	17	5
122	97	22	27	7
125	86	20	27	6
126	135	39	39	15
128	47	10	13	6
132	56	12	18	4
133	130	42	36	19
134	12	5	2	2
135	64	21	20	8
141	57	17	19	7
147	49	20	23	6
149	97	25	33	13
TOTAL (actual)	918	265	288	102
Calculated (9 : 3 : 3 : 1)	884.7	294.9	294.9	98.3

$$X^2 = 4.58 \quad P > 20$$

The weak-midrib is weak up to 5 cm from the top of the leaf-sheath after which it loses its individuality and becomes like one of the nerves in the blades (Fig. 11). Even this trace of the midrib is lost in the top leaves and the flag is midribless. Detailed measurements taken in 10 plants in each of the groups, normal and weak-midribs, show that in height of plants, thickness of internodes, number of leaves, length and breadth of leaf-blades,

duration and in general panicle shape, both the groups are alike. Besides the weakness in the midrib, the only difference is a distinct pull-down in the tillering capacity which is inevitable owing to the disability imposed upon the photosynthetic equipment. In the normal plants the thickness of the midrib of the fourth leaf from the top is 2.0 mm at the base, 1.2 mm at the middle and 0.027 mm at the top which is the same as the thickness of the blade. In the case of the same leaf with the weak-midrib it is 0.7 mm at the base, 0.5 mm at the middle, and 0.27 mm at the top. These measurements explain the drooping down of the ribbon-like leaves.

The consequences attendant on the presence of the weak-midrib are of still greater interest. Owing to the rarity of this occurrence, practically every plant with a weak midrib was carefully examined in all its parts. Along with the suppression of the midrib there is a suppression of the style and stigma (Fig. 12). In most cases these organs are completely absent and in stray cases vestiges of the style are present. Concurrent with the suppression of the style and stigmatic tissue there is a suppression of the tissue of the awn. Whether the spikelets are 'nil'-awned or long-awned the normal lemma is distinctly bifid, with a strong awn-base which protrudes only a short distance if it is 'nil'-awned (Fig. 13) or to a greater distance if it is long-awned (Fig. 14). In the weak-midribbed plants when the style and stigma are completely absent, the lemma is entire (bifid nature not seen) (Fig. 15) and there is no specialised tissue connecting the awn-base. When occasionally the vestiges of the styles are present, there is concurrently a faint manifestation of the awn-base (Fig. 16).

The genetics of the awn has been worked out and the 'nil'-awned condition (extreme reduction in length) is dominant to the long-awned condition. In a dihybrid segregation from normal and weak-midrib, and 'nil'- and long-awned condition instead of the theoretical 9 3 3 1 ratio, there occurred a 9 3 4 ratio as will be seen from the following table.

TABLE

Selection Number	Normal-midrib		Weak-midrib	
	'Nil'-awn	Long-awn (9-11 mm)	'Nil'-awn	Long-awn (9-11 mm)
S 118	18	9	9	
122	89	30	34	
124	43	16	23	
125	77	29	33	
126	134	40	54	..
128	39	18	19	
132	46	21	22	..
133	128	44	55	..
135	63	22	28	
137	84	23	34	
141	29	12	13	.
144	57	17	26	.
TOTAL (actual)	807	281	350	..
Calculated (0 3 4)	809.1	269.7	359.6	.

$$X^2 = 0.74 \quad P > 0.50$$

The awn segregation in the weak-midrib plants is not felt, due to the lack of awn tissue (homologous to the midrib). Gene *md* which affects the midrib affects also the homologous awn tissue. The very intimate connection between the midrib and the awn easily explains this phenomenon. It has been shown, that when the leaf-blade is forked, the awns are forked likewise<sup>25</sup>. When a severe attack of *Sclerospora* occurred and affected the leaf-blade, there was a suppression of the awn<sup>26</sup>. The effect of the weak-midribbed condition does not stop with this concurrent effect on the

leaf-blade and the awn, but also extends to the style and stigma. The homology between stigma and awn in sorghum has been given in great detail in a number of publications<sup>18, 27, 28, 29</sup>. Gene *md* affects the style and stigma vitally and they are entirely absent or only the rudiments of the style are present.

This accounts for the non-setting of seed in the flowers of the weak-midribbed plants, though the earhead is normal and the anthers emerge quite normally. The other effects of this weak-midribbed condition are the occasional presence of a fully developed dorsal lodicule<sup>30</sup> and in stray cases a second set of three anthers.

These experiences are of very great interest in the evolution of plant organs. The homology between the leaf-blade and awn, and between style and stigma and the column and subule of the awn has been well established. This experience in Sudan grass threads up all the three homologous organs, viz., midrib, awn and stigma. A serious disturbance in vegetative equipment produced catastrophic effects on the homologous reproductive equipment<sup>31</sup>. Such abnormal characters, resulting in sterility, could be produced by X-ray treatment, but their occurrence in nature is possibly to be explained through mutation induced in a new environment.

Coming to grain sorghums an instance is on record in which a cross between *S. durra* of Coimbatore and *S. nigrans* of Tanganyika (with pedicelled spikelets fertile)<sup>32</sup> gave in the F<sub>1</sub> a few plants whose side-shoots showed midribless leaves. Another interesting experience is worth recording here. Bulbils in earheads are a rare occurrence<sup>33</sup>. One such bulbil was nursed till it produced an earhead. In that plant of abnormal origin two leaves had no midribs. The first seedling-leaves in all sorghums do not elaborate a midrib<sup>30</sup>.

These interesting experiences are useful in throwing helpful light in the evolution of the Gramineæ, their leaf-sheath, leaf-blade and ligular and auricular equipment, glume and awn structures, lodicular, stylar and stigmatic elaborations, and help us to appreciate the big advance they have made in having their present equipment which has helped them to become the premier group among crop plants.

#### Summary

An agro-botanical description of the Sudan grass (*S. sudanense*, Stapf) is given and the many affinities to cultivated sorghums are mentioned. Sudan grass is believed to have contributed to the origin of the cultivated sorghum *S. dochna*. The rare and simple recessive characters, viz., e-ligulate

leaves and compact-spindle panicles and the rare dominant character, purple-washed pedicelled spikelets (gene PW) occur in both *S. suda*nense and in *S. dochna*. Besides these, characters experienced only in Sudan grass so far, are also described. Seedlings with banded chlorophyll deficient areas have been met with. This character has proved a simple recessive to the normal whole green. A gene cb is responsible for this character. There are two types of seedling habits, viz., open and erect. The former is a simple dominant to the latter and the gene SO is behind this character. Rare types with faint longitudinal stripes on leaves have occurred and have proved a simple recessive (gene cs) to the normal non-striped condition (gene CS). There is a great pull down in the waxy bloom condition in this grass. Even in this poverty of manifestation the very sparse condition (on leaf-sheath and internode) is a simple dominant to the extremely sparse condition (traces on the boot only). The gene controlling the angle which the primary branches make with the central stalk of the panicle does not determine a similar disposition of the secondary branches to the primary one. A new gene Pa<sub>2</sub> makes the secondary branches pulvinate and divergent to the primary branch. Gene pa<sub>2</sub> results in the absence of the pulvinus in the secondary branches (and consequently the secondary branches are adpressed to the primary branch). The Sudan grass has thrown light on the evolution and arrangement of the spikelets in sorghum in general, as the spikelets are sparse. The spikelets are arranged in a dichasial cyme with an alternate development. The sessile spikelets represent the older ones and explain the two waves of anthesis in sorghum. A proliferated earhead in which the lower panicle branches turned foliate is recorded. Cercals, which are also grasses, tiller. Tiller ing is an aspect of vigour. In Sudan grass the gene responsible for tillering TX could be isolated and is a simple monogenic dominant to the non-tillering condition tx. Gene tx produces weak single-stalked plants in which the basal and underground axillary buds are absent. Their panicles are weak, spurred and rod-like, and the spikelets are few and cluster at the terminals. The glumes are long, papery and develop long nerves. The pedicelled spikelets are practically absent being reduced to mere scales. The plants do not survive the shoot-borer attack and this is due to the inability to produce tillers in replacement of the main shoot. Gene tx has however no effect on the higher axillary buds. Next to the tiller-less single-stalked condition is the uniform tillering habit. Gene tu is responsible for this. Though many tillered, their gush of growth (want of a slow spaced development induced by gene TU) results in exhaustion and consequent weakness. TU is a simple monogenic dominant to tu. A strong midrib is an essential equipment in the long

leaf-blades in grasses, especially in cereals Gene MD produces the normal strong midrib Gene md results in a weak-midrib that makes the leaf ribbon-like and droop down The midrib being homologous to the awn and stigma, there is a concurrent suppression of the awn and of the stylar and stigmatic organs Gene MD has been found to be independent of gene C<sub>BL</sub> which produces bluish-green seedling leaves

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FIG. 1  
E-ligulate Plant



FIG. 2  
E-ligulate



FIG. 3  
E-ligulate

Divergent

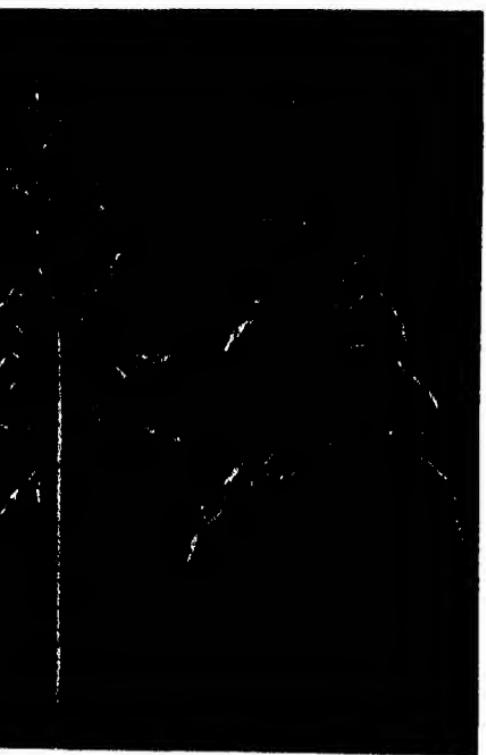


FIG. 4

Adpressed



FIG. 5

Panicle—lower branches turning foliate



FIG. 6

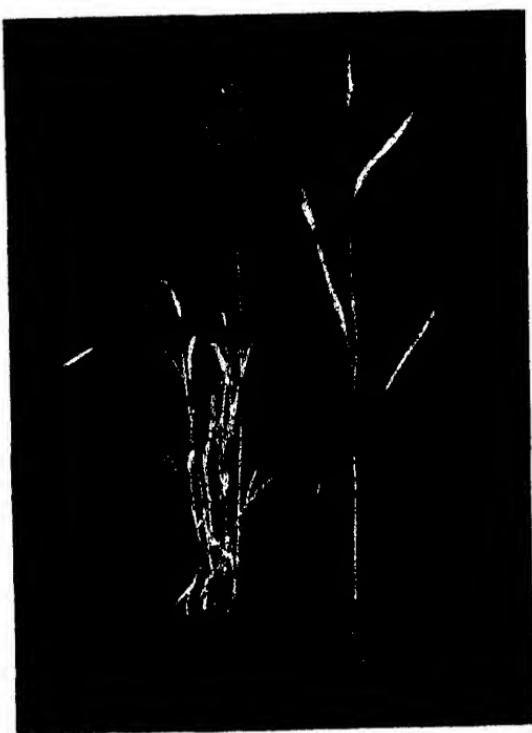


FIG. 7  
Whole Plants



← Spur



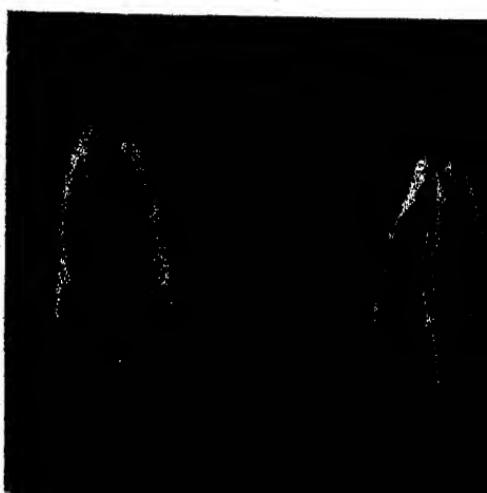
FIG. 10. Whole Plants



FIG. 11. Leaves



FIG. 12. Ovaries



## LAMELLIBRANCHS FROM THE BAGH BEDS

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LIKE the rhynchonellids<sup>1</sup> and bryozoa<sup>2</sup> from this formation, lamellibranchs also have not until now, received proper attention. As a species useful for purposes of correlation Duncan<sup>3</sup> had mentioned among the Bagh fossils the presence of *Neithea quadricostata* Sowerby, a species marking the Upper Green Sand horizon in England and many other countries. P N Bose<sup>4</sup> gave a list of lamellibranch species, which, however, as mentioned by him, were only tentatively diagnosed, and as such have helped us little in assigning any definite age to the Bagh Beds. Lately P N Mukerjee<sup>5</sup> has studied a small collection of molluscan fossils from the Jhabua and Ali Rajpur States. But the material available for him, being much ill-preserved has contributed little to our knowledge of the lamellibranch fauna of this formation. *Protocardium pondicherriense* d'Orb., and *Cardium (Trachycardium) incomptum* d'Orb., both from the Trichinopoly stage of the South Indian Cretaceous Series, are the only lamellibranch species which he could definitely identify from among his collection, while the rest of them are either diagnosed only generically or names of the comparable species are mentioned.

The material collected by the present writer being, however, quite extensive and well preserved has yielded a large number of species with more or less well-marked Cenomanian affinities, thus confirming the results of the study of other groups of fossils from this formation.

Besides the species described below, there are in the author's collection some specimens of *Ostrea*, which are, however, too fragmentary to be described.

<sup>1</sup> Chiplonker, 1938, pp 300-16

<sup>2</sup> Chiplonker, 1939 a, pp. 98-109.

<sup>3</sup> Duncan, 1865, p. 354, 1887, p. 81

<sup>4</sup> Bose, 1888, pp. 37-43

<sup>5</sup> Mukerjee, 1938, p. 196.

*Description of Species*

Family . Pinnidae  
 Genus . *Pinna* Linneus, 1758

*Pinna mathuri* sp. nov  
 (Plate XIII, Fig. 4)

*Description*—This species is represented by two incomplete specimens. The surface of each valve is angulated in the middle thus giving a rhomboidal cross-section. The valves are not fissured medianly. The dorsal part of each valve is almost flat and the ventral one feebly convex. The growth lines are very fine and are seen as low indistinct folds near the ventral margin. The surface of the valves is ornamented with seven or eight ribs on the dorsal part and six or seven ribs of the same strength on the ventral part. Each of the shallow concave interspaces carries an intercalary rib. All the ribs are slightly but conspicuously flexuous.

*Comparison*—This species can be distinguished from *Pinna laticostata* Stoliczka,<sup>6</sup> from the Utatur and Ariyalur stages of the Cretaceous Series of Trichinopoly District, by the presence of intercalary ribs in all the interspaces. *P. arata* Forbes<sup>7</sup> can similarly be distinguished from the species described here, by the former having the intercalaries only on the dorsal part of its valves.

As compared to *P. vanhaepeni* Rennie,<sup>8</sup> an upper Cretaceous species from Pondoland, the present species has its valves less angulated in the middle, the ventral part of the valves carries more ribs and there is an intercalary in each of the interspaces. But with all these differences these species appear to be closely related.

*Occurrence*—Nodular Limestone and Deola-Chirakhan Marl

Family . Pernidae  
 Genus . *Inoceramus* Sowerby, 1819

*Inoceramus pseudo-latus* sp. nov  
 (Plate XII, Fig. 3)

*Description*—The shell is rather tumid and oval, and obliquely elongated. The anterior side is short and rounded. The shell is elongated postero-dorsally. The surface of the shell is covered with thick fairly close-set folds and concave depressions which are much wider than the folds.

<sup>6</sup> Stoliczka, 1871, p. 385, pl. 25, figs. 2-3; pl. 26, fig. 4.

<sup>7</sup> Forbes, 1848, p. 153, pl. 16, fig. 10; Stoliczka, 1871, p. 384, pl. 24, fig. 5; pl. 25, fig. 1; pl. 26, fig. 5.

<sup>8</sup> Rennie, 1890, p. 172, pl. 18, fig. 9.

The umbones are acute and slightly turned. The greatest inflation of the shell is situated a little above the middle. The shell has in its posterior third, a ridge-like elevation extending from the umbo to the postero-ventral extremity.

*Comparison*—In comparison to *Ino multiplicatus* Stoliczka<sup>9</sup> from the Trichinopoly stage of the South Indian Cretaceous, the present species has its shell more oblique, longer and more tumid, its umbones are more anteriorly situated, the concentric folds on the surface are closer and the shell has a ridge-like elevation.

*Ino latus* Mantell<sup>10</sup> from the Cenomanian of Central Europe and England very closely resembles this species. The difference, however, lies in the latter having the ridge-like elevation and a less apiculate shell.

*Occurrence*—Deola-Chirakhan Marl

*Inoceramus lamarchi* var. *indicus* var. nov  
(Plate XII, Fig 1)

*Description*—The shell is very high and obliquely prolonged postero-ventrally. The umbones are produced and slightly incurved. The surface of the shell is covered with distant and rather prominent folds, and indistinct concentric striations.

*Comparison*—This species is comparable with *Ino simplex* Stoliczka<sup>11</sup> from the Ariyalur stage of South India. The latter species has, however, a shell less oblique and shorter, and the posterior margin is less convex.

As compared to *Ino lamarchi* var. *cuvieri* Sowerby,<sup>12</sup> from the Upper Chalk of England to which it is very closely related, the present form has its umbones less incurved and its shell less inflated.

*Occurrence*—Deola-Chirakhan Marl

*Inoceramus* sp. A  
(Plate XII, Fig 5)

*Description*—The shell is oval to pear-shaped, nearly as high as long and not much inflated. The anterior side is short and rounded, the ventral margin is strongly convex and has a weakly developed angulation. The

<sup>9</sup> Stoliczka, 1871, p. 406, pl. 28, fig. 1

<sup>10</sup> Sowerby, 1829, pl. 582, figs 1-2; Mantell, 1822, p. 216, pl. 27, fig. 10, d'Orbigny, 1844-48, p. 513, pl. 408, figs 1-2, 1850, p. 197, Morris, 1854, p. 170, Zittel, 1866, p. 100, pl. 18, fig. 7; Geinitz, 1872-78, p. 45, pl. 13, figs. 4-5; Woods, 1904-12, p. 279, pl. 48, figs 5-6, text-fig. 86.

<sup>11</sup> Stoliczka, 1871, p. 408, pl. 28, figs. 3-4.

<sup>12</sup> Woods, 1904-12, p. 320, pl. 53, fig. 7, text-figs. 73-84.

surface is covered with rather distant, prominent, concentric folds alternating with broad depressions. The umbones are pointed and slightly turned. The thickness of the shell is approximately one-third of the length and is situated a little above the middle of the shell.

*Comparison*—As compared to *Ino crispianus* Stoliczka<sup>13</sup> (non Mantell) from the Ariyalur stage of the Cretaceous Series of Southern India, the present species is much shorter and flatter.

*Ino cf. percostatus* Muller<sup>14</sup> from the Trigonia Sandstone of the North Saghalin, in comparison to the present species, is longer and has its concentric folds a little further apart.

*Occurrence*—Nodular Limestone and Deola-Chirakhan Marl

*Inoceramus* sp. B

A few large-sized specimens in fragmentary condition are comparable to *Ino striatus* Mantell<sup>15</sup> from the Cenomanian and Senonian of Bohemia.

*Occurrence*—Deola-Chirakhan Marl and probably also the Nodular Limestone

Family	Pectinidae
Genus	<i>Neitheia</i> Drouet, 1824

*Neitheia morrisi* Pictet and Renevier

(Plate XII, Fig 7)

- |         |   |
|---------|---|
| 1845    | <i>Pecten quinque-costatus</i> Forbes, <i>Q J G S</i> , Vol I, p 249 (in part)  |
| 1858    | <i>Janira morrisi</i> Pictet and Renevier, <i>Méthr Pal Suisse</i> , Ser 1, p 128, pl 19, fig 2                                       |
| 1865    | <i>Janira morrisi</i> Coquand, <i>Apptien Espagne</i> , p 341   |
| 1870    | <i>Janira morrisi</i> Pictet and Campiche, <i>Méthr Pal Suisse</i> , Ser 5, p 244   |
| 1901-02 | <i>Vola morrisi</i> Choffat, <i>Faune Crét Port</i> , Vol 1, Ser 4, p 147, pl 4, figs 5-6   |
| 1903    | <i>Pecten (Neitheia) morrisi</i> (Pictet and Renevier) Woods, <i>Mon. Cret Lam</i> , Vol 1, p 201, pl 39, figs 11-13                  |
| 1916    | <i>Neitheia morrisi</i> (Pictet and Renevier) Douvillé, <i>Mém Acad Sci</i> , Vol 54, Ser 2, p 171, pl 22, figs 17-18                 |
| 1934    | <i>Pecten (Neitheia) morrisi</i> (Pictet and Renevier) Nagao, <i>J Fac. Sci. Hok Imp Univ.</i> , (4), Vol 2, p 206, pl 26, figs. 2-6. |

<sup>13</sup> Stoliczka, 1871, p 405, pl 25, figs 1-8, pl 28, fig. 2.

<sup>14</sup> Yabe and Nagao, 1925, p. 115, pl. 28, figs. 7-8; pl. 29, fig. 10.

<sup>15</sup> Geinitz, 1871-73, p. 210, pl. 46, figs. 9-13; 1872-73, p. 41, pl. 18, figs. 1, 2, 9, 10.

**Description**—This species is a small race, the largest of the specimens measuring 24.4 mm in height. The shell is fan-like and a little higher than long. The ears are small and smooth except for the faint growth lines. The convex valve carries six, convex, major radial ribs with two secondary ribs much smaller than the major ones, in each of the five interspaces. The major ribs are flanked by very fine thread-like costæ on either side. The interspaces are concave and narrower than the ribs in the dorsal region, but become nearly equal to them near the ventral margin. The lateral areas on the convex valve carry two or three, rarely four, very fine radial ribs.

**Comparison**—This is the most abundant of the lamellibranch species in the Chirakhan area. These specimens from the Bagh Beds agree essentially well with the Aptian-Albian type of Pictet and Renevier, except that the fine thread-like costæ on either side of the primary ribs are absent in some of the specimens, and the areas carry two or three radial rib-lets such as are found in the Japanese specimens,<sup>16</sup> though Woods<sup>17</sup> says that in *N. morrissi* the areas are typically smooth.

Duncan<sup>18</sup> and P. N. Bose<sup>19</sup> had reported the presence of the widely distributed species *Neithaea quadricostata* Sowerby and *N. quinquecostata* Sowerby, in the Bagh Beds. An examination of the material in the collection of the writer as well as in the collection of the Geological Survey of India, has not revealed any specimens that could be assigned to either of these almost world-wide species of Sowerby. All these specimens, however, clearly belong to this widely occurring species of Pictet and Renevier.

**Occurrence**—Deola-Chirakhan Marl

Family	Spondylidæ
Genus	<i>Plicatula</i> Lamarck, 1801

*Plicatula spinicostata* sp. nov

(Plate XIII, Fig. 3)

**Description**—It is a small-sized species having the shell of an oval outline, the lower valve very feebly convex and the upper one nearly flat. The surface of the shell is ornamented with numerous rather coarse spiny ribs all of sensibly the same size, as a common feature the ribs do not increase by division at the successive growth stages.

<sup>16</sup> Nagao, 1934, p. 207.

<sup>17</sup> Woods, 1900-03, p. 202.

<sup>18</sup> Duncan, 1865, p. 354, 1887, p. 84.

<sup>19</sup> Bose, 1888, p. 40.

*Comparison*—This species might at first sight be confused with *Plicatula multicostata* Stoliczka<sup>20</sup> from the Trichinopoly stage of the South Indian Cretaceous Series. The present species has, however, its upper valve flattened and the lower one is comparatively much less convex, its ribs do not generally divide and are of sensibly the same size.

The species described here is very similar to *Pl. auressensis* Coquand<sup>21</sup> from the Cenomanian of Tunis and Egypt. The North African species has, however, in some individuals its upper valve feebly concave.

The present species shows the closest resemblance to *Pl. aspera* Sowerby<sup>22</sup> from the Alpine Turonian and Campanian. But the latter species has its lower valve more convex.

It would thus clearly appear that *Plicatula spinicostata* is related on the one hand to *Pl. aspera* Sow from the Alpine Turonian and Campanian and to *Pl. auressensis* Coquand from the Cenomanian of North Africa on the other hand.

After *Nerthea morrisi* Pictet and Renevier, this is the next most abundant species in these strata, of the Narbada Valley.

*Occurrence*—This species is recorded from the Deola-Chirakhan Marl and the Coralline Limestones.

#### *Plicatula batnensis* Coquand

(Plate XII, Fig. 5)

- |      |   |
|------|---|
| 1889 | <i>Plicatula batnensis</i> Coquand—Thomas and Peron, <i>Moll. foss. Tunisie</i> , p. 205, pl. 26, fig. 16 |
| 1912 | <i>Plicatula batnensis</i> Coquand—Pervinquière, <i>Étude Pal. Tunisienne</i> , p. 162, pl. 9, fig. 21    |
| 1917 | <i>Plicatula batnensis</i> Coquand—Fourtau, <i>Catalogue invert. foss. Égypt</i> , p. 22                  |

*Description*—The shell is broadly oval with both the valves very feebly convex. The surface is covered with numerous and rather coarse ribs without spines. The ribs do not increase by division. The growth stages are very scabrous.

<sup>20</sup> Forrer, 1876, p. 155, pl. 17, fig. 3, Stoliczka, 1871, p. 446, pl. 34, figs. 15–18; pl. 46, figs. 5–6.

<sup>21</sup> Lartet, 1880, p. 137, pl. 11, figs. 21–22, Thomas and Peron, 1890, p. 204; Pervinquière, 1912, p. 156, pl. 11, figs. 2–18, Fourtau, 1917, p. 20.

<sup>22</sup> d'Orbigny, 1844–48, p. 680, pl. 463, figs. 11–12, 1850, p. 254, Zittel, 1886, p. 120, pl. 10, fig. 1.

*Comparison*—These specimens from the Bagh Beds agree essentially with *Pi batnensis* Coquand from the Cenomanian of Tunis and Egypt. The only difference between the African representatives and these specimens from the Narbada Valley is that the latter have a slightly smaller number of ribs, a variation which is not unexpected in a species occurring in such widely separated regions.

*Plicatula instabilis* Stoliczka<sup>23</sup> occurring in the Ariyalur stage of South India and in the Campanian of Tunis might at first sight be confused with the present species, but the former species has fewer and much weaker ribs, which increase by division.

Like the previous species this is also quite common in the Chirakhan area.

*Occurrence*—Deola-Chirakhan Marl and Coralline Limestones

Family	Mytilidae
Genus	<i>Modiola</i> Lamarck, 1758

*Modiola inflata* sp. nov

(Plate XIII, Fig. 2)

*Description*—This species is roughly oblong and rather tumid at the anterior third of the length. The umbones are low and near the anterior side. The posterior region is slightly taller than the anterior one. The posterior margin makes an angle of about 55° with the very feebly convex ventral margin. The dorsal margin is almost straight. Anteriorly the shell is well rounded. The surface of the shell is covered with concentric growth lines. A ridge extends from the umbones postero-ventrally, with a feeble narrow depression along its length on the anterior side. A few radial striations are seen on this depression and on the anterior slope of the postero-ventral ridge.

*Comparison*—As compared to *M. vishnu* Noetling<sup>24</sup> from the mæstrichtian of the Mari Hills, Baluchistan, this species has its growth striae of the same strength throughout their course and the umbones are less anteriorly situated.

*Modiola typica* Forbes<sup>25</sup> from the Trichinopoly stage of the Cretaceous Series of South India and from the Alpine Gossau Deposits has, as compared

<sup>23</sup> Stoliczka, 1871, p. 445, pl. 34, figs. 3-14, pl. 16, fig. 3; Quaas, 1902, p. 175, pl. 20, figs. 16-22; Fourtau, 1917, p. 23.

<sup>24</sup> Noetling, 1897, p. 44, pl. 11, fig. 3.

<sup>25</sup> Forbes, 1846, p. 152, pl. 14, fig. 4; pl. 16, fig. 7; d'Orbigny, 1850, p. 247; Stoliczka, 1871, p. 377, pl. 23, figs. 12-15; Zittel, 1886, p. 78, pl. 11, fig. 5.

to the present species, its posterior side much more expanded and the posterior margin more inclined to the dorsal margin

*Modiola lensi* Quaas,<sup>26</sup> an upper Cretaceous species from the Lybian Desert can be distinguished from the present species by its antero-ventral region less inflated and much smaller than the postero-dorsal region, by the absence of radial striations along the postero-ventral ridge and by the greatest inflation situated sub-medianly

As compared to *M. reversa* Sowerby,<sup>27</sup> a Cenomanian species in England and Europe, this species has its posterior margin less sinuous

This species shows the nearest relation to *M. roquesi* Thomas and Peron<sup>28</sup> from the Cenomanian of Tunis, the latter has, however, its posterior margin more oblique

*Occurrence*—This species is recorded from the Deola-Chirakhan Marl

*Modiola minor* sp. nov

(Plate XII, Fig. 6)

*Description*—The shell is rectangular, rather high and tumid with fairly prominent umbones. The anterior side is very short and rounded. The ventral margin is almost straight. A ridge extends postero-ventrally from the umbones and sets apart an attenuated dorsal area. Except for the concentric growth lines the surface of the shell is smooth.

*Comparison*—From the associated *M. inflata* sp. nov., this species differs in having a much taller shell, its umbones more prominent and no radial striations on the postero-ventral ridge.

As compared to *M. typica* Forbes<sup>29</sup> from the Trichinopoly stage of the South Indian Cretaceous and the Alpine Gossau Deposits, the present species has its umbones more anteriorly situated, its shell a little shorter with the posterior margin less oblique and the posterior region less expanded.

*Modiola lensi* Quaas<sup>30</sup> from the upper Cretaceous of the Lybian Desert, comes closest to the present species. The difference, however, lies in the

<sup>26</sup> Quaas, 1902, p. 193, pl. 22, fig. 11.

<sup>27</sup> d'Orbigny, 1844-48, p. 277, pl. 861, figs. 1-2; 1850, p. 165; Morris, 1854, p. 211; Pictet and Campiche, 1867, p. 510; Geinitz, 1871-78, p. 216, pl. 48, fig. 9; Woods, 1900-08, p. 94, pl. 15, figs. 15-18; pl. 16, figs. 1-3.

<sup>28</sup> Thomas and Peron, 1890, p. 247, pl. 27, fig. 18.

<sup>29</sup> Forbes, 1846, p. 152, pl. 14, fig. 4, pl. 16, fig. 7; d'Orbigny, 1850, p. 247; Stoliczka, 1871, p. 377, pl. 23, figs. 12-15; Zittel, 1866, p. 78, pl. 11, fig. 5.

<sup>30</sup> Quaas, 1902, p. 193, pl. 22, fig. 11.

former species having a little longer shell and the postero-dorsal region is proportionally smaller than the antero-ventral region

*Occurrence* — Probably Upper Coralline Limestone

Family . Astartidae

Genus .. *Opis* Defrance, 1828

*Opis corniformis* sp nov

(Plate XII, Fig 2)

*Description* — The shell is very high and trigonal with prolonged, acute, slightly incurved beaks. The antero-ventral side is obtusely rounded and the postero-dorsal side is almost straight. A rounded carination extends from the umbo to the postero-ventral angle and cuts off a posterior area which is divided into two parts by a rounded secondary ridge extending to the postero-dorsal angle. The posterior area between the carinae is concave. The lunule is large and deep.

*Comparison* — This species can be distinguished from *Opissoma geinitziana* Stoliczka<sup>21</sup> from the Utatur stage of South India, by its beaks more prolonged, ventral margin less convex and the antero-ventral margin more rounded.

To compare with the present species, *Opis bicornis* Geinitz<sup>22</sup> from the upper Cenomanian of Bohemia, has its beaks shorter and less incurved, its shell more oblique and its ventral margin more convex.

*Opis elegans* d'Orbigny<sup>23</sup> from the Turonian of Sarthe has, as compared to the present species, its shell more oblique, beaks less produced and more incurved.

The species described here shows a very close affinity to *Opis haldonensis* Woods,<sup>24</sup> an Upper Green Sand species from England. The only observable differences are that the Indian specimens have slightly more prolonged beaks and a little shorter shell.

*Occurrence* — Deola-Chirakhan Marl and Nodular Limestone

Family . Crassatellidae

Genus *Anthonya* Gabb, 1864

*Anthonya tumida* sp nov

(Plate XIII, Fig 1)

*Description* — The shell is roughly trigonal, nearly twice as long as high and strongly inflated at about one-fourth the height from the umbones.

<sup>21</sup> Stoliczka, 1871, p 288, pl 10, fig 11.

<sup>22</sup> Geinitz, 1871-73, p 227, pl 50, figs 1-3

<sup>23</sup> d'Orbigny, 1844-48, p. 35, pl 254, figs. 4-9

<sup>24</sup> Woods, 1904-12, p. 119, pl. 18, fig. 1.

The ventral margin is very feebly convex. A ridge extends from the umbones to the postero-ventral extremity, setting apart a feebly concave dorso-posterior area. The umbones are situated at about one-fourth the length from the anterior side. Fine radial striations are observable only on the postero-dorsal area, while the rest of the surface shows only faint concentric growth lines.

*Comparison*—As compared to *An. cantiana* Woods,<sup>25</sup> a Gault species from England, the species described here has a taller and more inflated shell.

To compare with *Anthonya sub-cantiana* Nagao<sup>26</sup> from the Albian of Japan, the Indian species is more inflated and has a little higher shell.

*Anthonya linea* Kitchin<sup>27</sup> from the Uitenhage Series has its shell less tumid, more sub-equilateral and a little longer with its umbones placed less anteriorly.

*Occurrence*—This species is recorded from the Deola-Chirakhan Marl

Family	Cardinidae
Genus	. <i>Protocardia</i> Beyrich, 1845

*Protocardia pusilla* sp. nov

(Plate XII, Fig 8)

*Description*—This species is a small-sized race, the largest of the individuals measuring nearly 21 mm in length. The shell is nearly sub-circular and slightly longer than high. The ventral and anterior margins are regularly rounded and postero-ventrally there is a slight angulation. The shell is thickest at a little above the middle of the shell. The ornamentation consists of very fine, concentric rib-lets 9 to 11 per 5 mm in the middle region. The posterior region of the shell is covered with fine, smooth, radial rib-lets, the extent of this posterior region varies from one-fourth to one-fifth of the shell surface.

*Comparison*—In comparison to *Proto hillana* Sowerby,<sup>28</sup> a species of very wide distribution in Europe, Africa and South India, and ranging from the Cenomanian to Senonian, the species described above is a much

<sup>25</sup> Woods, 1904-12, p. 130, pl. 19, figs 4-5

<sup>26</sup> Nagao, 1934, p. 222, pl. 25, fig 11; pl. 30, figs. 6-7

<sup>27</sup> Kitchin, 1913, p. 137, pl. 7, figs. 7-8.

<sup>28</sup> Sowerby, 1812, p. 41, pl. 14; d'Orbigny, 1844-48, p. 27, pl. 243; Forbes, 1846, p. 146; d'Orbigny, 1850, p. 182; Pictet and Campiche, 1867, p. 288; Geinitz, 1871-73, p. 230, pl. 1, figs. 11-12; Thomas and Peron, 1890, p. 276; Quax, 1902, p. 218, pl. 24, fig. 18; Fourtau, 1904, p. 331; Woods, 1906, p. 307, pl. 37, fig 6; 1904-12, p. 197, pl. 31, fig. 6, pl. 32, figs. 1-6; Pervinquière, 1912, p. 264; Lehner, 1937, p. 140.

smaller race, its shell is a little longer than high and its umbones are a little more prominent

*Proto parahillana* Wade<sup>39</sup> from the Ripley Formation of North America as compared to the present species, has its outline more sub-circular and the umbones less conspicuous, also it has fine radial striations on the whole of the surface

*Occurrence* — Deola-Chirakhan Marl and the Nodular Limestone

Family . . . Isocardinidae

Genus . . . *Isocardia* Klein, 1753 \*

*Isocardia* aff *neglecta* Coquand

(Plate XIII, Fig 7)

*Description* — The shell is rather tumid, trigonal in outline and higher than long, the length being nearly equal to the thickness. The anterior side is short and rounded, postero-dorsally the shell is slightly tapering. The ventral margin is convex, being comparatively flatter in the middle than at the two ends. The beaks are incurved and twisted anteriorly. The maximum thickness of the shell is a little above the middle, while the greatest length is situated medianly.

*Comparison* — As compared to *Iso similis* Sowerby<sup>40</sup> from the Lower Green Sand of England, France and Switzerland the present species is taller, anteriorly more rounded and ventrally more convex.

In *Iso atlantica* d'Orbigny,<sup>41</sup> a Turonian species from France, the shell, as compared to that of the present species, is less inflated, slightly longer and posteriorly more angulated.

I did not have access to the original description and figures given by Coquand, but Fourtau<sup>42</sup> gives Coquand's diagnosis of *Iso neglecta* Coquand as "Coquille plus longue que large, oval, crochets légèrement contournés, étroits, écartés, moule intérieur montrant en arrière des crochets, une impression transversale". From this, it is obvious that the specimens described here are closely related to this species from the Cenomanian of Egypt. But since these specimens could not be compared with the original

<sup>39</sup> Wade, 1926, p. 87, pl. 27, figs 1, 5

\* Dall (in Zittel, 1927, p. 491) attributes the generic name *Isocardia* to Lamarck, while Fourtau (1917, p. 66) uses it after Klein, since I myself had not had access to the necessary literature for deciding the claims of priority, I use it here after Klein.

<sup>40</sup> Sowerby, 1826, p. 27, pl. 66, fig. 1; d'Orbigny, 1850, p. 163, Morris, 1854, p. 204, Pictet and Campiche, 1867, p. 240, Woods, 1904-12, p. 151, text-fig. 25

<sup>41</sup> d'Orbigny, 1844-48, p. 47, pl. 251, figs 3-6.

<sup>42</sup> Fourtau, 1917, p. 66.

figures, their identity with Coquand's species cannot be definitely established.

*Occurrence* — Deola-Chirakhan Marl and Nodular Limestone.

Family . .	Veneridae
Genus . .	<i>Callista</i> Poli, 1791

*Callista* sp. indet

(Plate XIII, Fig. 6)

*Description* — This species is represented by a number of casts which are longer than high, the maximum length lying a little below the middle. The shell is thickest slightly above the middle. The anterior and posterior margins are more strongly convex than the ventral margin. The umbones are situated a little anterior to the middle.

*Comparison* — Because of the general aspect of these casts they are comparable with *Callista plana* Sowerby<sup>43</sup> from the Upper Green Sand of England, France and Switzerland, but the present state of preservation of these specimens does not allow their identity being established.

*Occurrence* — Deola-Chirakhan Marl and Nodular Limestone.

Family	Sportellidae
Genus	<i>Anisodonita</i> Deshayes, 1860

*Anisodonita* sp. indet

(Plate XII, Fig. 4)

*Description* — These specimens are trapezoidal in outline. A strong carination separates a more or less flat dorsal area from the rest of the surface, it carries very indistinct radial striations while the rest of the surface shows only faint growth lines. The ventral margin is feebly convex. The anterior side is rather tapering. The umbones are turned slightly to the anterior and are situated at a little less than one-third of the length from the anterior end.

*Comparison* — The unfavourable state of preservation of the available specimens does not permit of a close comparison with any of the known species. But a reference might be made to *Aniso unzambiensis* Rennie<sup>44</sup> from the upper Cretaceous of Pondoland, which, however, is a longer species.

*Occurrence* — Deola-Chirakhan Marl.

<sup>43</sup> Sowerby, 1812, p. 58, pl. 20; Morris, 1854, p. 201; d'Orbigny, 1844-48, p. 447, pl. 380, figs. 1-8; 1850, p. 159; Woods, 1904-12, p. 192, pl. 30, figs. 1-6; Pictet and Campiche, 1867, p. 190.

<sup>44</sup> Rennie, 1930, p. 194, pl. 21, fig. 11.

Table showing the Affinities and the Vertical Distribution of the  
Lamellibranchia from the Bagh Beds

No	Species from Bagh Beds	Related species with geological horizon	Nodular Limestone	Lower Coralline Limestone	Deola Chirakhan Marl	Upper Coralline Limestone
1	<i>Pinna mathuri</i> sp. nov	<i>P. vanhaegehi</i> Rennie, Upper Cretaceous of Pondoland	×		×	,
2	<i>Inoceramus pseudo latus</i> sp. nov	<i>Ino latus</i> Mantell, Ceno- manian of England and Central Europe			×	
3	<i>Ino lamarckii</i> var. <i>indicus</i> var. nov	<i>Ino lamarckii</i> var. <i>cuvieri</i> Sow., Upper Chalk of England			×	
4	<i>Ino</i> sp. A	<i>Ino crispianus</i> Stol., Ariyalur stage of South India	×		×	
5	<i>Ino</i> sp. B.	<i>Ino striatus</i> Mantell, Cenomanian and Seno- nian of Bohemia	? ×		×	
6	<i>Nestrea morrisi</i> Pi- ctet and Renevier	<i>N. morrisi</i> Pictet and Renevier, Aptian and Albian of England, Spain, Switzerland and Japan			×	
7	<i>Plicatula spinis costata</i> sp. nov	<i>Pl. aspera</i> Sow., Turonian and Campanian of France and Germany, and <i>Pl.</i> <i>auressensis</i> Coquand, Cenomanian of Tunis and Egypt		? ×	×	×
8	<i>Pl. batnensis</i> Coquand	<i>P. batnensis</i> Coquand, Cenomanian of Tunis and Egypt		? ×	×	×
9	<i>Modiolopsis inflata</i> sp. nov	<i>M. roquesi</i> Thomas and Perou, Cenomanian of Tunis			×	
10	<i>M. minor</i> sp. nov	<i>M. leesa</i> Quaas, Upper Cretaceous of Libyan Desert				? ×
11	<i>Opis corniformis</i> sp. nov	<i>O. kildonensis</i> Woods Upper Green Sand of England	×		×	
12	<i>Anthonya tumida</i> sp. nov.	<i>A. subcantisana</i> Nagao, Albian of Japan			×	
13	<i>Protocardia pusilla</i> sp. nov.	<i>Proto parahilliana</i> Wade, Ripley Formation of U.S.A	×		×	

*Table showing the Affinities and the Vertical Distribution of the Lamellibranchia from the Bagh Beds—(Contd.)*

No.	Species from Bagh Beds	Related species with geological horizon	Nodular Limestone	Lower Coralline Limestone	Deola-Chirakhan Marl	Upper Coralline Limestone
14	<i>Inocardia</i> aff <i>neglecta</i> Coquand	<i>Ino</i> <i>neglecta</i> Coquand, Cenomanian of Egypt	X		X	
15	<i>Callista</i> sp indet	<i>C. plana</i> Sow Upper Green Sand of England France and Switzerland	X		X	
16	<i>Anisodontia</i> sp indet	<i>An. unzihensis</i> Rennie Upper Crataceous of Pondoland			X	

*Discussion of the Palaeontological Results and Conclusions*

As can be seen from the above table of distribution of the lamellibranch species, we find that out of the sixteen species which are recorded from this formation, all except one, namely *Modiola minor* sp nov., are present in the Deola-Chirakhan Marl. The species which occur in the Nodular Limestone include *Pinna mathuri* sp nov., *Inoceramus* sp A, *Ino* sp B, *Opis corniformis* sp nov., *Protocardia pusilla* sp nov., *Isocardia* aff *neglecta* Coquand and *Callista* sp indet., but all of them also occur in the Marl bed. Similarly *Plicatula spinicostata* sp nov., and *Pl. batnensis* Coquand are recorded both from the Marl and the Coralline Limestones. Thus, while most of the species known to occur in this formation, are recorded in the Marl bed, there are some species which it shares with the Nodular Limestone, and others which it has in common with the Coralline Limestones. These lamellibranch species, therefore, while being particularly abundant in the Marl, are not characteristically confined to any of the beds, so as to mark them out as distinct palaeontological zones or stages as was believed to be the case by Bose.

To discuss the faunal affinities and the age of the Lamellibranchia from the Bagh Beds, described in the foregoing pages, we have in these strata two species which are known also from outside India. Of these, *Neitheia morrisi* Pictet and Renevier, the commonest of the lamellibranch species in these beds, is known from the Aptian and Albian horizons in England, Spain, Switzerland and in Japan, while *Plicatula batnensis* Coquand, which also is an abundant species in this formation, is recorded from the Cenomanian of Tunis and Egypt. Another species, which is well represented in this formation, of which, however, the identity could not be established for

certain for want of the necessary literature, is *Isocardia* aff *neglecta* Coquand a very near ally of *Iso neglecta* Coquand from the Cenomanian of North Africa. Among the species which are described new, we have *Plicatula spini-costata*, sp nov, a species equally abundant as the last one, it is related on the one hand to *Pl aspera* Sowerby from the Turonian and Companian of the Alpine region, and to *Pl auressensis* Coquand from the Cenomanian of Tunis and Egypt on the other. To take the less common species, we have *Modiola inflata* sp nov, with its nearest ally *M roqueri* Thomas and Peron from the Cenomanian of Tunis; *Opis corniformis* sp nov, is allied to *O haldonensis* Woods, from the Upper Green Sand of England, and *Inoceramus pseudolatus* sp nov, is related to *Ino latus* Mantell from the Cenomanian of England and Central Europe.

From among the remaining species to consider those which are related to upper Cretaceous species, we have *Protocardia pusilla* sp nov, related to *Proto parahillana* Wade, from the Ripley Formation of the United States of America. *Modiola minor* sp nov, is allied to *M lensi* Quaas from the upper Cretaceous of the Lybian Desert, *Pinna mathuri* sp nov, has its nearest ally *P vanhaepeni* Rennie from the upper Cretaceous of Pondoland and *Inoceramus lamarcki* var *indicus* var nov, is closely related to *Ino lamarcki* var *cuvieri* (Sowerby) from the Upper Chalk of England.

It is thus clear that while these lamellibranch species from the Bagh Beds show a mixture of affinities towards species ranging from the Aptian to Senonian, a large proportion of them have Cenomanian affinities.

Mukerjee,<sup>45</sup> however, has lately tried to show that the Bagh Beds range from the Cenomanian to the Upper Senonian because of the range of affinities shown by his collection of Mollusca from the Jhabua and Ali Rajpur States. In his report on these beds he records the presence of *Astarte*, *Mactra* (?), *Aucella* (?), *Nucula*, *Ostrea*, *Melania*, some *Auriculid* *Pulmonata*, *Cidaris* and *Bryozoa*, and claims to have specifically identified *Protocardium pondicherriense* d'Orbigny, *Cardium (Trachycardium) incomptum* Sowerby, *Macrocallista* cf *sculpturata* Stoliczka, *Grotriana* cf *jugosa* Forbes, *Crassinella* cf *planissima* (Forbes), *Cr* cf *trigonoides* (Stoliczka) and *Turritella* (*Zaria*) *multistriata* Reuss. Out of these, he mentions *Proto pondicherriense*, *Card (Trach.) incomptum*, *Macrocall* cf *sculpturata* and *Turr multistriata* as typical South Indian upper Cretaceous forms suggesting that the Bagh Beds probably range up to the upper Senonian, while the presence of characteristic Utatur forms *Grotriana* cf *jugosa* and *Crassinella* cf *planissima* show that the Bagh Beds range down to the Cenomanian.

<sup>45</sup> Mukerjee, 1934, pp. 71-73, 1935, pp. 80-81; 1938, pp. 190-98

From this list given by Mukerjee it is clear that the only species of which he can be said to have definitely established the identity are only three, namely *Protocardium pondicherriense* d'Orb., *Cardium (Trachycardium) incomptum* Sowerby and *Turritella (Zaria) multistriata* Reuss. Of these, the first two are from the Trichinopoly stage, where only the second species is reported to be common, while *Turritella multistriata* is recorded in South India from the Ariyalur and Trichinopoly stages where it is not reported to have any particularly important position, it is also known from the Senonian and Turomian of the Lybian Desert, Germany and the Alpine region<sup>46</sup>. The remaining four species which Mukerjee records in the Bagh Beds of his area, are only comparable with some of the South Indian species which, moreover, are not of any special importance in those deposits. It is unfortunate that Mukerjee has used the terms "characteristic or typical species" in too loose a sense as can be seen from the above remarks. None of the species which Mukerjee records in the Bagh Beds of Jhabua and Ali Rajpur States, are in any sense "characteristic" or "typical" of any of the stages in the South Indian Cretaceous Series, nor are any of them particularly important in the Bagh Beds. They, therefore, cannot be of any value in fixing the age of the Bagh Beds with any more precision than, that they indicate an upper Cretaceous age for this formation.

It is thus clear from the foregoing discussion, that this series of strata forms a single palaeontological unit, in which Cenomanian affinities are the predominant element of the fauna, it is therefore, reasonable to assign to this formation the Cenomanian age.

Mukerjee's collection is, however, of some interest in so far as it includes the three South Indian species *Protocardium pondicherriense* d'Orb., *Cardium (Trachy) incomptum* Sowerby and *Turritella (Zaria) multistriata* Reuss. It brings in under discussion the possibility of faunal connections between the Narbada Valley and the Trichinopoly District. Except *Pinna mathuri* sp. nov., which is allied to *P. arata* Forbes from South India and also to *P. vanhepeni* Reune from Pondoland, there are no Bagh species related to those from South India. As is clear from the author's work on other groups of Bagh fossils<sup>47</sup> also, the Bagh fauna have strong affinities towards those from North Africa and Southern Europe. Since, of the three South Indian species mentioned above, *Turritella multistriata* Reuss is also

<sup>46</sup> Forbes, 1846, p. 124; Stoliczka, 1868, p. 224; Geinitz, 1871-73, p. 161; Quens, 1802, p. 246.

<sup>47</sup> Chiplonker, 1937, pp. 66-68; 1938, pp. 312-13, 1939, pp. 242-45; 1939 a, pp. 105-07.

known to occur in the Lybian Desert, Germany and in the Alps, the affinities of *Pinna mathuri* towards *P. arata* and *P. vanhaefteni*, as well as the occurrence in the Narbada Valley, of *Protocardium pondicherriense* and *Cardium (Trachy) incomptum* in association with *Turritella (Zaria) multistriata* might be expected through the African and the Mediterranean regions and not by any direct connection as was suggested by Bose. While it is admitted that the explanation given above might account for the occurrence of these South Indian species in the Narbada Valley, it is also likely that a closer examination than hitherto done, of the molluscan fauna of the Jhabua-Ali Rajpur area might show these species to be specifically different from the two above-mentioned South Indian species.

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## EXPLANATION OF PLATES

## PLATE XII

- FIG 1.**—*Inoceramus lamarchei* var. *indicus* var. nov.; showing right valve (B H U No L/3)
- FIG. 2**—*Opis corniformis* sp. nov., showing right valve (B H U No L/11).
- FIG. 3**—*Inoceramus pseudo-latus*, sp nov., showing right valve (B H U No L/2)
- FIG. 4**—*Anisodonta* sp indet., showing left valve (B II U No L/16)
- FIG. 5**—*Inoceramus* sp A, showing left valve (B H U No L/4)
- FIG. 6**—*Modiola minor* sp nov., showing left valve (B H U No L/10)
- FIG. 7**—*Neithaea morrisoni* Pictet and Renevier (a) showing left valve, (b) showing right valve, (B H U No L/6)
- FIG. 8**—*Protocardia pusilla* sp nov., showing right valve (B H U No L/13).

## PLATE XIII

- FIG 1**—*Anthonya tumida* sp nov., showing right valve (B H U No L/12)
- FIG 2**—*Modiola inflata* sp nov., showing right valve (B H U No L/9)
- FIG. 3**—*Placatula spinis-costata* sp nov., showing upper valve (B H U No L/7)
- FIG. 4**—*Pinna malhuri* sp nov., showing left valve, (B H U No L/1)
- FIG. 5.**—*Placatula batnensis* Coquand, showing upper valve (B H U No L/8)
- FIG. 6.**—*Callista* sp indet., showing right valve (B H U L/15).
- FIG 7**—*Iocardia* aff. *neglecta* Coquand, (a) showing left valve, (b) showing anterior view (B H U. No L/11)

N B—All the figures are natural size

All the figures are photographs of the plates drawn from the Type specimens under the author's supervision.



1



2



3



4



5



6



7a



8



7b

1

2

3

4

## ON SOME STONE IMPLEMENTS FROM HOSHANGABAD (CENTRAL PROVINCES)

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THE stone implements, which form the subject of the present contribution, were collected by the author from the banks of the river Narbada and neighbouring ravines, near Hoshangabad in the Central Provinces. So far the implements collected from the Narbada Valley by various workers are mostly confined to collections made from certain areas round about Jubbulpore and the literature available is mostly a record of the find. The very first account of some discoveries of worked flints from near Jubbulpore was given by Evans<sup>1</sup> in 1853, followed by LeMesuriar,<sup>2</sup> Sweney,<sup>3</sup> Carey,<sup>4</sup> Blanford<sup>5</sup> and Oakes.<sup>6</sup> In the year 1873, Medlicott<sup>7</sup> described a quartzite Celt found *in situ* by Hacket from Bhutra in the Narsingpur District in the Narbada Valley. This find is of exceptional importance as "Hacket himself dug it from where he found it lying flat and two-thirds buried, in a steep face of the stiff, reddish, mottled, unstratified clay about six feet above low water-level"<sup>8</sup> and which is about the same horizon at which some of the implements, described here, have been found. Mention of some palaeolithic and neolithic implements from near rock shelters about three miles from Hoshangabad town has also been made by Ghosh.<sup>9</sup> The present contribution contains the description of four palaeolithic and two neolithic stone implements, which are unquestionably of human manufacture and some of them have been found *in situ* in the same or about the same horizon in which the vertebrate fossils have been known to occur.

<sup>1</sup> Evans, 1853.

<sup>2</sup> LeMesuriar, 1861, pp. 81-85

<sup>3</sup> Swiney, 1869, pp. 17-18, 1865, pp. 77-79

<sup>4</sup> Carey, 1866, pp. 135-36

<sup>5</sup> Blanford, 1866, p. 290.

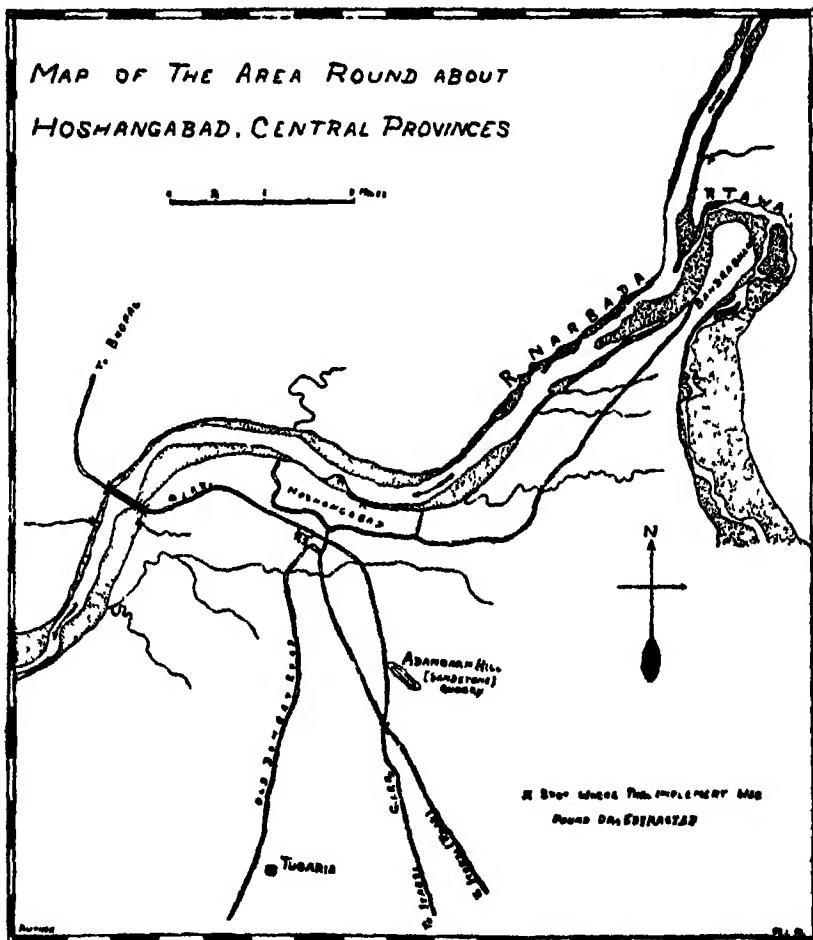
<sup>6</sup> Oakes, 1869, pp. 51-53

<sup>7</sup> Medlicott, 1873, pp. 49-53

<sup>8</sup> *Ibid.*, p. 49

<sup>9</sup> Ghosh, 1932, pp. 21-22.

Some fossilised remains of vertebrate animals have also been collected by the author along with the implements and these have been handed over to Prof D K Chakravarti of this University for study



The area covered in collecting these implements is about 10 miles in length along the banks of the river Narbada running from about a mile to the east of Bandrabhan a locality at the confluence of the Narbada with the Tawa, to about a mile to the west of the railway bridge over the Narbada near Hoshangabad town. Two other localities, a small sandstone hill containing some old red coloured paintings in the rock shelters, about  $1\frac{1}{2}$  miles to the south-east of the Hoshangabad town and a laterite quarry, at the village Tugaria about four miles to the south of the town, were also investigated but no implement was found.

The general stratigraphical succession of beds at the banks of the river in the area investigated is as follows in the descending order —

Beds	Approximate Thickness
Regur	8 feet
Yellow alluvium . . .	12 ..
Yellow alluvium with concretions . . .	8 ..
Gravels at places containing boulders	5 ..

The thickness of the various beds is not constant. The gravelly bed is conspicuous by constantly running along the banks forming a terrace. Due to the meanders of the river, this gravelly bed is, often, overlain and thus concealed by the recent deposits of sand. The yellow alluvium forms the thickest bed of the series. Just below Saddar Bazar in the Hoshangabad town all the beds are well exposed and attain a total thickness of about 35 to 40 feet.

As far the age of these deposits, the topmost bed is, no doubt, of recent time. The bottom bed (gravels) was considered, to be of Pliocene age by Falconer,<sup>10</sup> while in the opinion of Medlicott<sup>11</sup> "these old ossiferous alluvial deposits are not more ancient than the late Pleistocene". Both these views have been questioned by Das Gupta,<sup>12</sup> who is of opinion that the Narbada ossiferous gravels are not older than middle Pleistocene.

The author takes this opportunity of conveying his grateful thanks to Mr K Sripada Rao, Central College, Bangalore, for lending his personal copies of the two papers of Prof Sampat Iyengar. The author's sincere thanks are also due to Dr Rajnath, Head of the Department of Geology, Benares Hindu University and to Prof D K Chakravarti, of the same Department for facilities and help.

*Specimen No N/19 (B H U)*

Plate XIV, Fig 1

The specimen is fashioned out of brownish looking fine-grained Vindhyan quartzite with a predominant yellowish tinge. It is almond shaped, mostly symmetrical, and has not been retouched. The 'surface d'accommodation' is like an inverted U, with diverging arms. The two points, at which these diverging arms end, mark the greatest width of the specimen. From beyond these two points, the specimen begins to narrow.

<sup>10</sup> Medlicott, 1873, Pt. 3, p. 49.

<sup>11</sup> *Ibid*, p. 54.

<sup>12</sup> Das Gupta, 1923, p. 22.

down towards the 'surface d'utilisation', where it finally ends in a small semicircular edge about  $\frac{1}{2}$ " in width. A somewhat blunt edge all round the specimen forms the periphery which is undulating and contains a number of marks of chipping. One of the two main faces of the implement is made convex by three main bold strokes, the axis of convexity running along its greatest width. Two strokes, one on each side of the axis of convexity, have produced two surfaces. One of these two surfaces slopes towards the 'surface d'utilisation' and the other towards the 'surface d'accommodation'. The line along which these two surfaces meet forms a ridge which runs more or less along the greatest width of the specimen and coincides with the axis of convexity on this face. The third stroke not as bold as the other two is near about the middle of the right edge of the specimen and it has produced a third surface, small and triangular in shape, sloping towards the edge. This side shows some signs of retouching. The surface on the reverse side is also convex, but the axis of convexity here is along the length of the specimen and runs from the 'surface d'accommodation' to the 'surface d'utilisation'. From along this axis the specimen slopes mainly in two opposite directions towards the right and towards the left. Only one, roughly pentagonal surface, produced perhaps by only one bold stroke, forms the whole of the right-hand face. It is bounded by two edges and three ridges which are formed by conjunction of differently sloping surfaces. Two four-sided surfaces, comprise the left-hand face. These faces slope towards the edge from the main ridge. There is a small triangular area at the 'surface d'accommodation' bound by two ridges and one edge. The main ridge of the specimen coincides with the axis of the convexity and slightly bulges towards the left.

The specimen weighs 7 oz. Its greatest length from 'surface d'accommodation' to the 'surface d'utilisation' is 3 9", the greatest width 3.2" and the greatest thickness 1.05"

The specimen bears a very close resemblance, in practically all the details, to a boucher from the Cuddapah District of the Madras Presidency figured by Coggan Brown<sup>13</sup>. It also resembles K. Sripada Rao's specimen No. Z 6/441<sup>14</sup>. The only main point of difference between these two is that the present specimen is marked by the absence of notches, and this negatives the idea of the present specimen having ever been used with a handle. On the other hand, the smooth and convenient grasp at the 'surface d'accommodation' and its close resemblance to Coggan Brown's

<sup>13</sup> Coggan Brown, 1917, pl. I, fig. 1.

<sup>14</sup> Sripada Rao, 1930, pl. VI, figs. 1, 2, 3.

boucher point strongly towards this specimen being designed for a hand-grasp, and used as a hand axe.

The specimen was found *in situ* and was extracted from the steep face on the left bank of the river Narbada near Hoshangabad. It was found embedded just below a gravelly bed containing vertebrate fossils, about 6 to 8 feet above the lowest water-level.

The bold and rough design of the implement and a smooth and comfortable hand-grasp indicate that the implement probably belongs to Chelean Culture, but appears to be more primitive either to Hacket's find<sup>15</sup> or to that of Wynne<sup>16</sup>.

*Specimen No N/20 (B H U)*

Plate XIV, Fig 2

The specimen is fashioned out of hard, compact, brownish looking ferruginous Vindhyan sandstone, which is found in abundance round about the locality where it was found. It is evidently an almond-shaped side-scraper with semicircular 'surface d'utilisation'. The 'surface d'accommodation' is thick and convenient for a hand-grasp. The bulb of percussion is well developed by a bold stroke at the 'surface d'accommodation' on one of the two main faces. Two deep scars or 'eraillures' can be very clearly seen on the bulb of percussion. One of these is along the edge of the 'surface d'accommodation' and the other one, which is slightly curved, is at right angles to the first. Excepting these two scars and the well-developed bulb of percussion, the specimen does not show any other major signs of chipping. Few small chips have been taken out along some portions of the 'surface d'utilisation'. The other corresponding opposite face of the specimen presents enough marks to show that the implement has been fashioned mostly on this side. This face shows three main surfaces sloping in different directions towards the edges from a common point. These faces have been produced in the attempt to get a sharp edge and convenient hand-grasp. The semicircular working edge shows all along a number of marks of chipping. On both the sides the specimen has a general slope from the 'surface d'accommodation' to the 'surface d'utilisation'.

The implement measures 3 75" along its greatest length and 3 0" along its greatest width. Its greatest thickness at the 'surface d'accommodation' is 0 75". The specimen weighs 4 7 oz. It bears a very close resemblance to one side-scraper from Pilt-down gravels so prominently figured by

<sup>15</sup> Medlicott, 1878, p. 49.

<sup>16</sup> Oldham, 1868, p. 65.

Boule,<sup>17</sup> Osborn<sup>18</sup> and Sollas<sup>19</sup> The specimen was found embedded, rather loosely, in a sort of boulder or gravelly bed which projects into the bed of the river near Hoshangabad town The spot from where it was extracted lies about 6 to 8 feet above the low water-level of the river

As for the age of the implement nothing very definite can be said as the specimen has not been found truly *in situ* The fact that it is worked on one side only and that it is a side-scraper with a bulb of percussion which is a characteristic of the Mousterian industry, leads one to believe that the implement belongs to the Mousterian age But the consideration that the implement was found embedded, though loosely, near about the same horizon as that of N/19, described in this paper, and which is of Chellean Culture, negatives the idea of its being of Mousterian age The view that the implement belongs to Mousterian time further loses support when it is considered that "although flints worked on one side only were formerly regarded as characteristic of Mousterian civilisation, they are very often, sometimes to the exclusion of the other forms, found also in the Chellean,"<sup>20</sup> and also that "the form of the chipped implements is not always a sure criterion of the particular cultural stage which is represented by it"<sup>21</sup> Therefore, the present author feels inclined to believe that the age of this implement is Chellean rather than Mousterian

*Specimen No N/21 (B H U)*

Plate XV, Fig 3

The specimen is made out of hard, fine-grained, compact, brownish looking dark Vindhyan sandstone It is roughly almond-shaped, crudely fashioned and unretouched One side the bulb of percussion is sufficiently well developed with shallow, thin, "eraillure" The face containing the bulb of percussion, further shows a few other marks of chipping at the 'surface d'accommodation' as well as at the 'surface d'utilsatlon' These chips were evidently taken out in order to provide a comfortable hand-grasp and a sharp working edge The opposite corresponding face shows one prominently triangular surface, and two other surfaces the boundaries of which are not clearly defined The periphery is undulating and all along the edge marks of chippings are evident, but towards the working face they become more prominent

<sup>17</sup> Boule, 1928, fig 94

<sup>18</sup> Osborn, 1927, p 127, fig 60, 1 and 1a.

<sup>19</sup> Sollas, 1924, p. 191, fig 81

<sup>20</sup> Boule, 1928, p 161.

<sup>21</sup> Das Gupta, 1923, p. 4.

The implement measures along its greatest length, from 'surface d' utilisation' to 'surface d'accommodation' 4 25" and 3 2" along its greatest width It assumes greatest thickness of 1" at the bulb of percussion The specimen weighs 7 oz

In appearance and by the presence of the bulb of percussion the implement appears to be a side-scraper But the edge just opposite to the bulb of percussion is very blunt and thick This side is 0 5" thick and consequently does not provide in anyway, a working edge for the implement, so that it may be used as a side-scraper The real 'surface d'utilisation' is provided by a V-shaped edge One arm of this V ends in the bulb of percussion and the other in the blunt edge, opposite to the bulb of percussion The number of marks of chippings at this V edge proves that this obviously has been done only to provide a sharp working edge more convenient for chopping This being the 'surface d'utilisation', the surface opposite to this automatically becomes the 'surface d'accommodation' and this provides a very convenient and comfortable hand-grasp along with two dents for the fingers at the side Hence this implement is more likely to be a coupe-de-poing than a side-scraper It may have been originally designed to serve as a side-scraper but afterwards probably, either intentionally or accidentally was transformed into a hand axe

The specimen was found lying loose at a distance of about 50 yards from where the specimen No N/20 was extracted It seems to belong to earlier Palaeolithic Culture more probably Chellean

*Specimen No N/22 (B H U)*

Plate XV, Fig 4

The implement is fashioned out of hard, brownish, ferruginous, compact Vindhyan sandstone It is massive and heavier than the other implements described here The implement is roughly circular in shape and double convex in appearance It is thick at the 'surface d'accommodation' and slopes gradually towards other directions till it thins out at the periphery and forms a semicircular edge The edge is quite sharp and the periphery is undulating specially along the working edge The working face shows more marks of chipping on one side of the implement than on the other Out of the two main faces of the implement, one shows gradual bulging from the 'surface d'utilisation' and becomes very prominent towards the 'surface d'accommodation' where the specimen becomes very thick This face is marked by having a few radial striae which make this still more undulating towards the 'surface d'utilisation' Towards the 'surface d'accommodation' this face has one more surface which is inclined to it This surface is triangular in shape with rounded corners and

sides bulging out. The whole side shows marks of prominent chippings along the edge. The corresponding face on the reverse side shows a tendency towards flatness, but no doubt, it too shows a very gradual rise from the edges towards the 'surface d'accommodation', where the specimen possesses a prominent but depressed bulb of percussion with two very clear eraillures on each side of the origin of the bulb. The bulb of percussion has lost its prominence due to the thickness and the massiveness of the specimen. The face shows some concentric striae which of course start from the bulb of percussion and are seen even upto the 'surface d'utilisation'. They are shallow and flat and not at all prominent. Like the reverse face, this face too, possesses a triangular surface, with rounded corners and the sides bulging outside, at the 'surface d'accommodation'. This face also contains marks of chippings which are very prominent at the 'surface d'utilisation'.

The specimen weighs 17 oz. It measures 5 2" along its greatest length, and 4 45" along its greatest width. It is 1 5" thick at the butt end. The implement was found near the confluence of the river Narbada with the Tawa about six miles at the east of the Hoshangabad town. It was picked up from the bed of a ravine in the land between the two rivers, which shows no outcrop of any sandstone.

This implement, without doubt, was intended to be a scraper with a semicircular face. But looking to its size and weight it becomes doubtful if it was used as such. The hand which wielded it must have been powerful and big to have a convenient grasp to use it as a scraper. With an average modern hand it can very well be used as a hand axe, for the purpose of chopping or cutting. The specimen, with its size and weight must have afforded an unique implement for cutting the branches of the trees. As for the age, the implement seems to belong to Mousterian Culture. It bears a very close resemblance to a Mousterian side-scraper figured by Schmucker<sup>22</sup>. It also resembles in shape to a flake No 2436 figured by R. B. Foote<sup>23</sup>.

*Specimen No N/23 (B H U)*

*Plate XVI, Fig 5*

Fashioned out of fine-grained, brownish looking ferruginous Vindhyan sandstone, elongated with pointed butt and curved edges, this celt or hatchet falls in groups 4 and 10 given by Coggin Brown<sup>24</sup>. The specimen

<sup>22</sup> Schmucker, 1925, p 79, fig 25

<sup>23</sup> Foote, 1916, pl XII.

<sup>24</sup> Coggin Brown, 1917, p 6

is tapering towards the butt end along its length. The butt end is bluntly pointed. The specimen shows three faces, two main ones, opposite to each other and the third at one of the sides. The side face is more or less an elongated hexagonal area, the elongation being along the length of the specimen. There is a small bulb of percussion on this surface with a prominent, elongated "eraillure" and few marks of mild strokes for retouching the bulb of percussion. Out of the two main faces, one shows a convexity, the axis of the curve being along the width of the specimen and near about its central part. This face is devoid of any marks of fashioning, except a slight dent towards the left. The whole face looks like a trapezium with rounded corners and bevelled edges, the butt end being its shortest side. The corresponding opposite face, includes one small triangular area at the butt end. This area is inclined to the main face. At the union of these two faces there is a ridge. This triangular area seems to be the result of chipping off a small flake with one bold stroke in order to provide a convenient accommodation surface. The main face, though flat, slopes gently towards the left till, at the union with the corresponding opposite faces, it forms an edge. Towards the 'surface d'utilisation' the specimen shows a number of marks of chipping. These marks are of mild strokes used evidently to obtain a sharp edge. The utilisation edge is adze-shaped, curved and sharp. The specimen seen as a whole is smooth and it appears that this has been achieved by grinding. Though the 'surface d'accommodation' gives a very convenient hand-grasp, it is very likely that the implement may have been mainly used with a haft.

The specimen measures 5 1" from the 'surface d'utilisation' to the butt end, 3 4" along its utilisation edge and 1 80" near the butt end. The thickness of the specimen at one of the lateral sides is 1 1" while the other side is a mere edge. It weighs 12 7 oz.

The specimen is a neolithic celt. It closely resembles the celt from Burma described and figured by Theobald<sup>25</sup> and also to one figured by Schmucker<sup>26</sup>.

The specimen was found loosely embedded, about half out, in yellow alluvium about 2 ft below its junction with black cotton soil. The spot from where it was extracted is near the mouth of a *nala* near the Railway bridge on the right bank of the river. It probably belongs to Campignian Culture.

<sup>25</sup> Theobald, 1874, pt. 2, pl. III, figs. 1 a and 1 b.

<sup>26</sup> Schmucker, 1923, p. 90, fig. 32.

*Specimen No N/24 (B H U)*

## Plate XVI, Fig' 6

This implement is obviously a crudely made hatchet and is fashioned out of olivine Basalt. It is thickest at the butt end and thinnest at the 'surface d'utilisation' with the result that it has got a tapering appearance. The two side-faces are triangular in shape, while the other three remaining faces are oblong. Except for one bold stroke at the butt end and one near an edge which shows a slight depression, the specimen shows no signs of chipping. All the different planes of the faces are tilted. This causes the specimen to appear like a solid trapezium. The edge, utilised for the cutting purposes, is slightly curved and the two end corners have been rounded. One side of this edge shows some indications of its having been ground just like a chisel.

The specimen shows uniformity in length and breadth but not in thickness. The length from the 'surface d'utilisation' to the butt end is 4 65" and the width is 2 2". The greatest thickness is 1.5" at the butt end and reduces itself merely to an edge at the 'surface d'utilisation'. The specimen weighs 14 oz.

It was found near the Railway bridge about three miles from the Hoshangabad town lying loose in the bed of a small *nala* on the left bank of the river Narbada. The specimen is fashioned out of olivine Basalt which does not occur near about the locality. The interesting feature of the specimen is in the presence of three marks of slightly brownish colour which appear to be originally due to grease or fat, and which are yet preserved in the implement. These marks point definitely that this implement has been fitted into a cloven handle and lashed with gut or stripes of wet hide or strong vegetable, the fat or grease of which has left these marks. If a haft is attached to this implement it will appear like a stone axe figured by W J Sollas<sup>27</sup>. Though this implement has not been found *in situ*, yet from the mode of its fashioning and the way in which it was used with a haft indicate clearly to this celt belonging to later Neolithic age perhaps Campignian or even Housian.

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<sup>27</sup> Sollas, 1924, p 269.

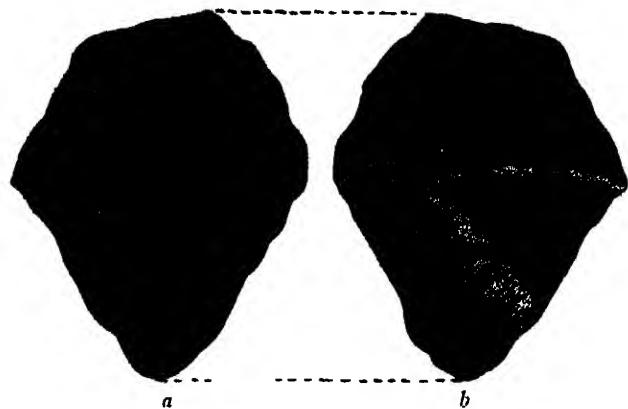


FIG. 1 Specimen No. N/19  $\times \frac{1}{2}$

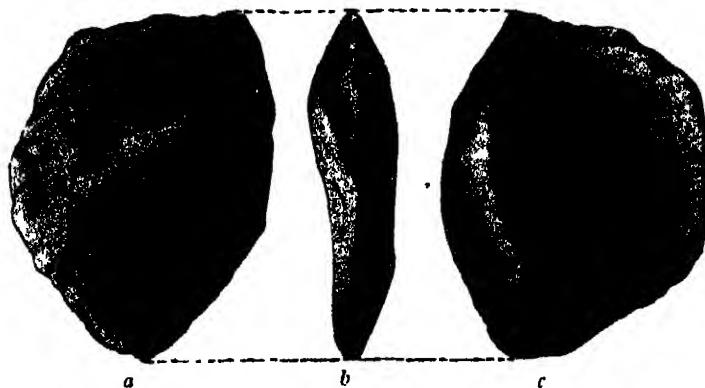


FIG. 2 Specimen No. N/20  $\times \frac{1}{2}$

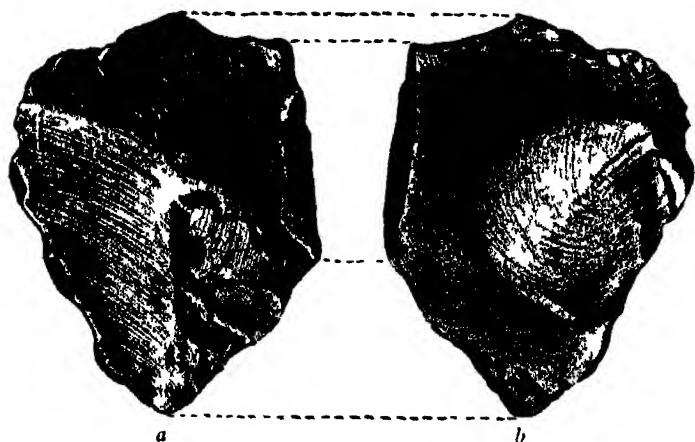


FIG 3 Specimen No N/21  $\times \frac{1}{2}$

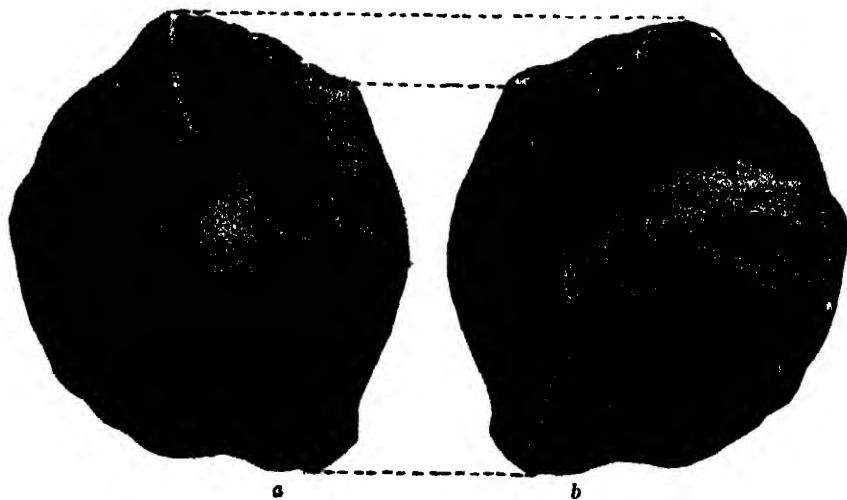


FIG 4 Specimen No N/22  $\times \frac{1}{2}$

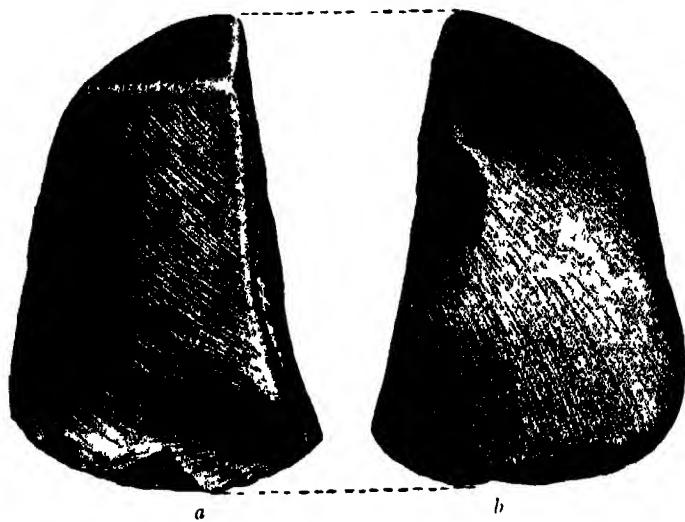


FIG 5 Specimen No N/23  $\times \frac{1}{2}$

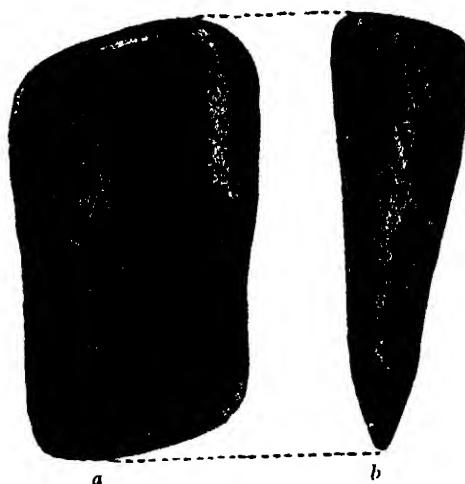


FIG 6 Specimen No N/24  $\times \frac{1}{2}$



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# ON SOME NEMATODE PARASITES FROM AFGHANISTAN

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(Communicated by Dr M. B. Mirza)

IN the following paper certain parasitic nematodes have been dealt with, which were recovered from different animals of this place, and a new species of the genus, *Ihubuneæ* Seurat, 1914, has been described. The writer is greatly indebted to Dr H. A. Baylis of the British Museum (Natural History), London, for the useful suggestions on *Syphaciella* and *Spirocerca*. He expresses his thanks to Dr G. D. Bhalerao, Helminthologist, Veterinary Institute, Mukteswer, for kindly providing him with the necessary literature. He is also thankful to Dr M. B. Mirza, Director, Zoological Laboratories, Aligarh, for kindly going through the paper.

1 Family *Strongylidae* Baird, 1853 — Sub-family *Strongylinae* Railliet, 1893 — Genus *Strongylus* Mueller, 1780, or Goeze, 1782 *Strongylus equinus* Mueller, 1780

Host — Horse Location — Caecum

2 Family *Oxyuridae* Cobbold, 1864 — Sub-family *Oxyurinae* Hall, 1916 — Genus *Passalurus* Duj., 1845 *Passalurus ambiguus* (Rudolphi, 1819)

Most of the rabbits which were dissected in the laboratory, were found infected with the parasite

Host — Rabbit Location — Colon

Genus *Enterobius* Leach, 1853 *Enterobius vermicularis* (Linn., 1758)

Host — Child Location — Rectum (Faeces)

Genus *Dermatoxys* Schneider, 1866 *Dermatoxys* sp.

Among many (about 50) rabbits dissected, only two were found infected. The specimens were, unfortunately, lost in the course of study, and hence their specific determination not done. The examination, however, confirmed Mirza's observations "the cervical alæ in certain specimens extend beyond the oesophageal bulb, while in others they are shorter and above it or

terminate at the level of the oesophageal bulb, i.e., the length of the cervical alæ may differ in male and females of the same species."

Host—Rabbit Location—Colon

Sub-family *Cosmocercinae* Railliet, 1916—Genus *Syphaciella* Monnig, 1921 *Syphaciella indica* Mapstone, 1931

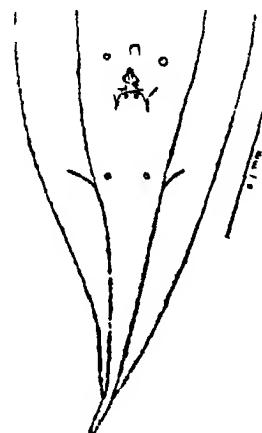


FIG. 1 *Syphaciella indica* Tail of male, ventral view

These worms are the same as those of *Syphaciella indica*, but the writer finds five instead of four pairs of caudal papillæ in the male. Mapstone seems to have overlooked one pair of comparatively large and conical papillæ which is situated immediately behind the cloacal aperture. The tips of the papillæ of this pair are often bent towards each other. As the specimens of the writer were not quite mature, it was very difficult to see the most posterior pair but one, and so this pair of the caudal papillæ is not shown in the diagram.

Host—*Pterocles* sp (Local name Burnaqara) Location—Cæcum

3 Family *Spiruridae* Oerley, 1885—Sub-family *Spirurinae* Railliet, 1916—Genus *Spirocera* Railliet and Henry, 1911 *Spirocera lupi* (Rud., 1809) (= *S. sanguinolenta*)

A pair of the worms of this species was recovered from the aorta of a domestic cat of Kabul. They were quite mature, but of much smaller size than that given in literature. The species occurs in the dog, wolf, jackal and fox, and has also been transmitted to cat experimentally. Therefore it appears that they have occurred there accidentally and their smaller size is connected with the fact that they were in an unusual host.

The male measures 8 962 mm in length and 0 540 mm in thickness, the female 31 421 mm and 0 654 mm respectively. The buccal cavity is about 0.070 mm long. The oesophagus is 5 247 mm long in the male and 6 558 mm in the female. The left spicule is 2.305 mm long and the right 0 600 mm in the female the tail is 0 283 mm long and the vulva is 0 083 mm from the posterior end of the oesophagus. The eggs measure 0 026 × 0 010 mm.

Host —Cat Location --Aorta

4 Family *Physalopteridae* Leiper, 1809 —Sub-family *Physalopterinae* Railliet, 1893 —Genus *Thubunæa* Seurat, 1914 *Thubunæa baylisi* N. Sp \*

The cuticle is coarsely striated and lateral alæ are absent. The head bears a pair of submedian cephalic papillæ. The mouth is with two lateral rounded lips, the internal surfaces of which are armed with three blunt and forwardly directed tooth-like structures. The pharynx is short and with delicate walls. The oesophagus is clearly divided into two parts, an anterior muscular and a posterior glandular. The cervical papillæ are situated near and behind the nerve-ring and the posterior part of oesophagus begins in front of the cervical papillæ. The excretory aperture is behind the cervical papillæ and the intestine is straight.

The male measures 14 334 mm or more in length and 0 286 mm in thickness near the middle of the body. The head is 0 043 mm in diam., and the length of pharynx is about 0 049 mm. The first part of the oesophagus is 0 190 mm in length while the second part is 1 393 mm.

The nerve-ring is situated at about 0 167 mm, the excretory aperture at 0 300 mm and cervical papillæ at 0 207 mm from the anterior end of the body.

The caudal alæ are well developed, quite symmetrical, finely striated transversely and meeting ventrally in front of cloacal aperture. The tail is 0 246 mm long simply conical and digitiform and slightly curved to the dorsal side. The ventral surface of the tail with papilliform elevations exhibiting a verrucose appearance. There are altogether thirty caudal papillæ—16 on the left and 14 on the right side. The spicules are subequal, lightly chitinised, and about 0 150 mm long, their proximal ends nearly truncate and distal pointed.

The female measures 22 016 mm or more in length and 0 400 mm in diam near the middle of the body. The head is 0 063 mm in diam

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\* The species is named after Dr H. A. Baylis of the British Museum, London (England)

and the pharynx is 0.056 mm in length. The first part of the oesophagus is 0.193 mm long while the second part is 1.667 mm.

The nerve-ring is situated at about 0.217 mm, the excretory aperture at 0.313 mm and cervical papillæ at 0.273 mm and vulva at 3.083 mm (or at about 1/7 of the total length) from the anterior end. The vulva is a little salient and the vagina is 0.134 mm long, is nearly right-angle to the body surface. The eggs are with thick shells and contain larvae when deposited. The larva is 0.007 mm thick and the size of egg is 0.050 × 0.037 mm.

The tail is 0.400 mm in length and terminates into a small conical process.

Six species of the genus *Thubuncæ* have been so far described. *T. pudica* by Seurat in 1914, *T. parkeri* and *T. asymmetrica* by Baylis in 1926 and 1938, *T. fitzsimonsi* by Ortlepp in 1931, and *T. greycola* and *T. agamæ* by Sandground in 1933. The new species *T. baylisi* differs from all the above-named species in most of the measurements and is differentiated from all of them by its lips armed internally with only three blunt forwardly directed teeth. The posterior part of the oesophagus begins near and behind the nerve-ring. In spite of the peculiar arrangement of its caudal papillæ, the caudal alæ are symmetrical and join with each other in front of the cloacal aperture. The vulva is situated at about the anterior 1/7 of the body length.

Host -- *Agama* sp. Location — Stomach

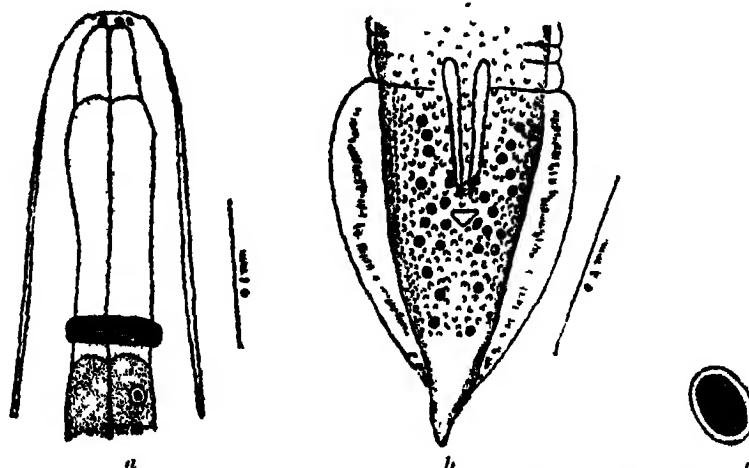


FIG. 2 *Thubuncæ baylisi*. a—Anterior extremity of female, lateral view; b—Posterior extremity of male, ventral view; c—Egg

The type specimens of the new species have been deposited in the Museum of the Zoological Laboratories, Muslim University, Aligarh

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## A SYSTEMATIC ACCOUNT OF SOME SOUTH INDIAN DIATOMS\*

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(Communicated by Dr M O P Iyengar)

THE number of papers dealing with systematic accounts of Diatoms from the different parts of India has been so far very few. The first important account of the diatom flora of the Indian region was given by Grunow (1865) in a paper on the Diatomaceæ and Desmidiaceæ of the Island of Banka near Singapore. In this paper he gives an account of 31 species of diatoms from the island. Previous to this Wallich in 1860 recorded 2 diatoms from the digestive cavities of the Salpæ. Zeller in 1873 recorded one diatom from Burma. The following foot-note in his paper states, "The diatoms from Burma (about 60 or more species) are not yet described, Dr L Rabenhorst of Dresden has, however, been kind enough to undertake the determination of them (S Kurz)." I am not able to trace if any account of these diatoms has been published anywhere. In 1882 George Dickie in a paper on some algae from the Himalayas gives an account of 28 diatoms. Leuduger-Fortmorel (1879) has given an account of a number of diatoms from Ceylon. He (1893) has also recorded nine diatoms from Malaya and the neighbouring areas. Schaarschmidt (1886) in a paper on Afghanistan algae, has given an account of 22 diatoms. W West and G S West (1902) has recorded 49 diatoms from Ceylon. In 1907, they published a paper on the Fresh Water Algae from Burma including a few from Bengal and Madras, wherein they have given an account of 59 species, of which two were from Vizagapatam in South India. Prain (1905) recorded three forms from Hughli-Howrah districts. Carter (1926) in her account of some algae from North India recorded 49 diatoms. Skvortzow (1930) recorded 99 forms from Ceylon, and 56 forms from Calcutta (1935). Biswas (1932) has given an account of the records of diatoms from India by various workers upto 1932. He (1932, 1935) records 3 diatoms from Upper India and 9 diatoms (1936) from the Loktak Lake, Manipur, Assam. In 1935 Abdul Majeed published a paper on the Panjab diatoms wherein he has given a detailed account of 62 forms.

\* From the University Botany Laboratory, Madras Thesis (in part) submitted for the degree of Master of Science in the University of Madras

It may be seen from the above that all the records have been from Upper India, Burma, Malaya and Ceylon, and that, with the exception of the two diatoms recorded by West and West (1907) from Vizagapatam, no work has been so far done on the Diatomaceæ of South India. I have therefore attempted to give a detailed account of the Diatomaceæ collected in this region.

This work was taken up at the suggestion of Prof M O P Iyengar. The diatoms dealt with in this paper comprise the collections of several people including some made by myself. Prof M O P Iyengar was kind enough to place his valuable collections from different parts of South India at my disposal. A good collection of diatoms from the Nilgiris was kindly handed over to me for examination by Dr T Ekambaram. The stomach contents of a fish caught in the river Adyar at Madras by Prof R Gopala Aiyar and of another caught by Dr B Sundararaj in the Periyar Lake, Travancore, were examined, and quite a number of diatoms were found in them †.

A large number of brackish-water diatoms was collected by me in connection with my paper on the ecology and seasonal succession of the diatom flora of the river Cooum which runs through Madras. A systematic account of these diatoms also is included in the present paper.

I take this opportunity of expressing my sincere thanks to all the above people for their kindness in placing their diatom material at my disposal. I also wish to thank my several friends who were kind enough to hand over at various times small samples for examinations.

All the drawings were made with the aid of a Zeiss Camera lucida with a Zeiss oil-immersion objective 90 (ap 1.25, m Iris) or 120 apochromat (ap 1.3) and with compensation ocular No 10 or 15. The drawings were made from specimens carefully cleaned, dehydrated and mounted in canada balsam.

The material is first treated with concentrated hydrochloric acid. After an hour, it is washed in water two or three times with the help of a centrifuge. It is then treated with an equal quantity of concentrated sulphuric acid to which a few crystals of potassium dichromate is added. The mixture is then

† Diatoms found in the stomach contents of the fish from Adyar :—

<i>Pleurosigma salinarum</i>	<i>Nitzschia obtusa</i> var. <i>scalpelliformis</i>
<i>Amphora coffeiformis</i>	<i>Nitzschia closterium</i>
<i>Navicula digitoradiata</i>	

Diatoms found in the stomach contents of the fish from Periyar :—

<i>Melosira granulata</i>	<i>Pinnularia interrupta</i> f. <i>genuine</i>
<i>Cyclotella Meneghiniana</i>	<i>Cymbella turgida</i>
<i>Eunotia pseudolunaria</i> sp. nov.	<i>Coconeis placentula</i> var. <i>euglypta</i>

allowed to stand for two to four hours. After thorough washing in water with the help of a centrifuge, the frustules are preserved in 6% formalin. In the case of diatoms with weakly silicified walls, dilute hydrochloric acid alone is used.

On a slide previously smeared with a thin coating of Mayer's albumen, a drop of the cleaned material is placed. This drop is either allowed to dry up of its own accord or gently heated over a flame to drive off all the water. The material on the slide is then dehydrated in 95% alcohol and then in absolute alcohol, and then given two changes in xylol and finally mounted in canada balsam.

Where the specimens are stray, the slide with the material on it is gently heated over a flame so that all the water evaporates. Then the material sticks to the slide. After cooling, the slide is placed in a jar containing concentrated sulphuric acid to which a few crystals of potassium dichromate is added. The slide is kept in the mixture from about 10 minutes to 6 hours depending upon the nature of the silicification of the diatoms. It is then washed in running water for about an hour and then passed through the alcohol and xylol and finally mounted in canada balsam.

On the whole 98 forms are described representing 33 genera, of these 98 forms, 67 are new records for India, 3 are new species, 6 new varieties and 6 new forms.

The classification of Hustedt (1930) was followed in the arrangement of the several forms. As far as possible, only those references that I was actually able to consult are given under the several species.

Bacillariophyta (Diatomeæ)

A Order CENTRALES

I Suborder DISCINEÆ

(1) Family COSCINODISCACEÆ

(a) Subfamily Melosiroideæ

Genus *Melosira* Agardh, 1824

Subgenus *Eumelosira*

I *Melosira dubia* Kutz

(Fig. 8)

Hustedt, Fr., Rabenhorn's *Archivogamen-Flora*, Bd. VII, Teil 1, 1930, p. 234, fig. 97.

Frustules in long chains united by gelatinous cushions. Frustules with short mantle portions and arched discs. Sulcus and neck absent. Pseudo-sulcus broad. Cell walls strong.

*Dimensions* \*—

Diameter . . . . .	17-38 $\mu$
Height of the half cell	8-14 $\mu$

*Habitat* — Brackish water Ennore back-waters, Madras (!)

The discs are more arched than in the type and look elongated in the specimens observed. The faint punctæ on the valve surface were not observed.

## 2 *Melosira granulata* (Ehr.) Ralfs

(Fig 1)

Schonfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 18, fig 9, Boyer, *Syn N Am Dnat*, 1927, p. 30, Hustadt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 87, fig 41, Hustadt, Fr., Rabenhorst's *Kryptogamen Flora*, Bd VII, Teil 1, 1930, p. 248, fig 101, a, b, c, e

*Melosira polymorpha* subsp *granulata* (Ralfs) Bethge; Bethge, *Kolkwitz Planzenforschung*, Heft 3, 1925, p. 30, Tafel 1, fig 1

Frustules cylindrical, robust and stiff in detached filaments. Mantle portions cylindrical, discs flat. Small pseudo-sulcus present. Sulcus somewhat shallow. Neck fairly big. Mantle line straight, parallel. Mantle surface punctate, puncta coarse in more or less spiral rows. The outer shell always coarsely punctate, their puncta rows being parallel. The same cells have spines projecting outside as well as inside the cells.

*Dimensions* —

Diameter . . . . .	8-12 $\mu$
Height of the half cell . . . . .	8-12 $\mu$
Rows of punctæ in the upper cell . . . . .	8- 9 in 10 $\mu$
No of punctæ in the upper cell . . . . .	8-10 in 10 $\mu$
Rows of punctæ in the lower cell . . . . .	10-14 in 10 $\mu$
No. of punctæ in the lower cell . . . . .	10-12 in 10 $\mu$

*Habitat* — Fresh water Plankton, Red Hills Lake, Madras, leg. S V Ganapati Periyar Lake, Travancore, from the stomach contents of a fish leg, B Sundararaj

This form agrees with the type

\* The dimensions given under the various forms in this paper are those actually found in the material examined by me.

3 *Melosira granulata* (Ehr) Ralfs var  
*angustissima* Mull

(Fig 2)

Hustedt, Fr., Pascher's *Stichworter-Flora*, Heft 10, 1930, p 88, fig 45, Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 1, 1930, p 250, fig 104, d

Filaments long with narrow and long cells, the height of the cells being several times the diameter

*Dimensions* —

Diameter	.	3-5 $\mu$ , mostly 4 $\mu$
Height of the half cell		11-14 $\mu$
Rows of punctæ in the upper cell		8-10 in 10 $\mu$
No of punctæ in the upper cell		8-10 in 10 $\mu$
Rows of punctæ in the lower cell		10-12 in 10 $\mu$
No of punctæ in the lower cell		10-12 in 10 $\mu$

*Habitat* — Fresh water Red Hills Lake, Madras, leg, S V Ganapati  
This form agrees with the type

(b) Subfamily *Skeletonemoideae*

Genus *Skeletonema* Greville, 1865

4 *Skeletonema costatum* (Grev) Cleve

(Fig 6)

Van Heurck, *Traité des Diatomées*, 1899, p 437, pl 33, fig 880-890, Gran, H H, *Nordisches plankton, Botanischer Teil*, Bd VIII, 1908, p XIX 15, fig 7, Hustedt, Fr., Rabenhorst's *Kryptogamen Flora*, Bd VII, Teil 1, 1930, p 311, fig 149, Labour, Marie, V, *Planktonic Diatoms of Northern Seas*, 1930, p 70, fig 43

Frustules weakly silicified Cells lens-shaped Ends of cells rounded Long spines connect the cells to form usually straight chains The spaces between the cells are longer than the cells themselves

*Dimensions* —

Diameter	..	6-5-14 $\mu$
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*Habitat* — Marine Plankton of the river mouth Cooum, Madras (!)  
This form agrees with the type

Genus *Thalassiosira* Cleve, 1873

5. *Thalassiosira marginata* sp nov.

(Figs 12, 13)

Frustules drum-shaped, quadrangular in girdle view, single, occasionally united in twos Valves round with two chromatophores more or less lobed

between which lies eccentrically a very small nucleus. Along the margin of the valve are present 18-22 small punctæ. The punctæ are seen in the girdle view also.

*Dimensions* —

Diameter	.. .	4-6 $\mu$
Marginal punctæ		18-22

*Habitat* — Brackish water River Cooum, Madras (!)

This form occurred as plankton of the river Cooum during the North-East Monsoon Season (Oct-Dec, 1936). Sometimes it was found in such enormous numbers as to impart a brownish yellow colour to the water. A similar thing was noticed by Kolbe and Tiegs in lower Werra because of the presence of a small species of *Thalassiosira* akin to the present one (Kolbe and Tiegs, *Ber d Deut Bot Ges*, Bd XLVII, 1929, p 418, Abb 2).

In girdle view the height of the diatom as compared with *Thalassiosira nana* Lohmann is much more in the present form than in Lohmann's figure of *Th. nana* (Hustedt, Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 1, 1930, p. 331, Fig 167 a, b). In girdle view the outline of the valve side is wavy in *Th. nana* whereas in this form it is quite straight and the sides parallel. In the case of *Th. nana* there are no striations or punctæ at the periphery of the valve view, but here, there are 18-22 punctæ clearly visible. Again, Lohmann's form has 4 chromatophores whereas there are only two in the present form.

This form agrees with Kolbe and Tiegs' form (*Ber d Deut Bot Ges*, Bd XI.VII, 1929, p 418, Abb 2) in certain respects, viz., the two chromatophores, the absence of the unpaired process and in the presence of the marginal punctæ. The marginal punctæ are 8-10 (constantly 9) in their form whereas in the present one they vary from 18-22. In the girdle view also the punctæ are seen along the margin.

(c) *Subfamily Coscinodiscorideæ*

Genus *Cyclotella* Kutzng, F T, 1834

6 *Cyclotella stelligera* Cleve and Grunow

(Fig 10)

De Toni, *Syll Alg*, Vol II, part 2, 1894, p 1355; Schönenfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 18, fig. 13; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 100, fig 65; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 1, 1930, p 339, fig 172.

Valves discoid, margins narrow, striae coarse and distinct. The middle field has a star-like structure with a central puncta and radiating thick and short lines.

**Dimensions —**

Diameter	11-13 $\mu$
Striae	. 10 in 10 $\mu$

**Habitat** — Fresh water As stray specimens in the plankton of an irrigation tank at Vandalur, Madras, leg., K G Veeraraghavan

The radiating short lines in the middle field as given in the descriptions are elliptic lanceolate in the specimens observed

**7 *Cyclotella Meneghiniana* Kütz**

(Figs 11, 14)

De Toni, *Syll Alg.*, Vol II, part 2, 1834, p 1354, Van Heurck, *Traité des Diatomées*, 1899, p 447, pl 22, fig 656, Boyer, *Syn N Am. Diat.*, 1926, p 38, Hustedt Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 100, fig 67, Hustedt Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 1, 1930, p 341, fig 174

Frustules discoid in valve view, rectangular and undulated in girdle view Margin well defined, coarsely striated and the striae wedge-shaped

**Dimensions —**

Diameter	11-30 $\mu$
Striae	8-10 in 10 $\mu$

**Habitat** — Fresh and brackish waters Common

The central portion at first sight appears to be quite smooth, but under very high magnifications show extremely fine radially arranged punctæ as figured by Van Heurck (*op cit*, pl 22, fig 656) This form agrees in all respects with the type It is found as a very common form in the ponds and pools and is also capable of accommodating itself to salinity This form occurs fairly in abundance in the plankton of the river Cooum and its development is stimulated through an increase in the salinity Therefore this form is grouped under "Halophilous forms" according to the classification of Kolbe

**8 *Cyclotella Kuizingiana* Thwaites**

(Fig 9)

De Toni, *Syll Alg.*, Vol II, part 2, 1894, p 1359, Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1918, p 10, fig 18, Boyer, *Syn N Am. Diat.*, 1926, p 38; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 98, fig 32, Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 1, 1930, p 398, fig 171 a

Frustules single, free floating Valves disc-shaped Central portion of the valve punctate, puncta scattered. Striations symmetrically radial, somewhat extending to the middle Near the margins they appear broken through their sparkling nature

*Dimensions —*

Diameter . . . . .	18-24 $\mu$
Striae . . . . .	12 in 10 $\mu$

*Habitat* — Brackish water River Cooum, Madras (1)

This form agrees quite well with the type

Genus *Coscinodiscus* Ehrenberg, C G, 1838

9 *Coscinodiscus Granii* Gough

(Pl XVII, Fig 2, Figs 16, 17)

Gran, H H. *Nordisches plankton, Botanischer Teil*, 1908 p XIX 34, fig 35; Hustedt Fr., Rabenhorst's *Kryptogamen-Flora* Bd VII, Teil 1, 1930, p 436, fig 237; Lebour Marie, V, *Plankton Diatoms of Northern Seas* 1930, p 44, fig 20

Valves rounded, aeriolated, aeriolations bigger in the centre The highest point in the valve is eccentric and therefore wedge-shaped in girdle view

*Dimensions —*

Diameter	229-240 $\mu$
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*Habitat* — Marine From the plankton of the river mouth Cooum, Madras (1)

Under a high magnification there appears to be a thickening like a nodule in the central portion of one of the valve surfaces The other valve has got a different pattern in the central portion

II Suborder BIDDULPHINAE

(2) Family CHAETOCERACEAE

Genus *Chaetoceros* Ehrenberg, 1844

Section *Brevicatenata*

10 *Chaetoceros orientalis* Schiller

(Figs 3, 4, 5, 7)

Hustedt Fr., Rabenhorst's *Kryptogamen-Flora*. Bd VII, Teil 1, 1930, p. 721, fig. 412

Chains long, straight and stiff Valves elliptical. Frustules connected to each other by a short process arising from the slightly gibbous middle portion of the cell Bristles long, thin and smooth End bristles stronger and longer

*Dimensions —*

Length of the valve (apical axis) . . . 10-15.5  $\mu$

*Habitat* — Brackish water Plankton of the river Cooum, Madras (1)  
Abundant in the month of September 1936

A solitary specimen with a resting spore (Fig 16) was found in the collection. The resting spore of this diatom has according to Hustedt (*op cit*, p 722) not been known previously. The resting spore has a smooth thick wall and in general shape resembles that of *Chaetoceros Muelleri* Lemm (*op cit*, p 756, fig 439) and *Chaetoceros subsalsum* Lemm (Kolbe, *Pflanzenforschung*, Heft 7, 1927, Taf II, Fig 28-31) which Hustedt considers it the same as *Chaetoceros Muelleri*.

In this connection may be mentioned Lebour's view (*Planktonic Diatoms of Northern Seas*, 1930, p 105). With regard to the resting spores of *Chaetoceros* Lebour says that "the young resting spores are often smooth, the armature coming on later". It is not clear whether the spore observed by me is only in a young condition which will develop armature later on. But the resting spores of *Chaetoceros Muelleri* and *Chaetoceros subsalsum* also show smooth walls. So it is just probable that the smooth-walled resting spore in my specimen represents the fully developed condition.

#### *Subfamily Anauileeae*

##### *Genus Terpsinæ Ehrenberg, 1843*

###### *11. *Terpsinæ musica* Ehr*

(Figs 15, 18, 19, 20, 21)

De Toni, *Syll Alg.*, Vol 11, 1891 p 891. Van Heurck, *Traité des Diatomées*, 1899, p 452, fig 178. Bover *Syn V im Diat.*, 1927, p 141. Hustedt *Ft*, Rabenhorst's *Kryptogamen-Flora*, Bd VII Teil 1, 1930 p 898 fig 510

Frustules in girdle view quadrangular, united in long zig-zag chains. The several septa of the frustule have their inner margins curved and slightly thickened resembling the musical notes. Valves linear, elliptical with undulating sides and slightly knobbed at the ends, divided by the septa into 5 to 7 parts. Surface coarsely punctate and finer at the ends. In some cases the surface is both punctate and reticulate, the reticulations being irregular. A central big pore is seen in the middle of the valve.

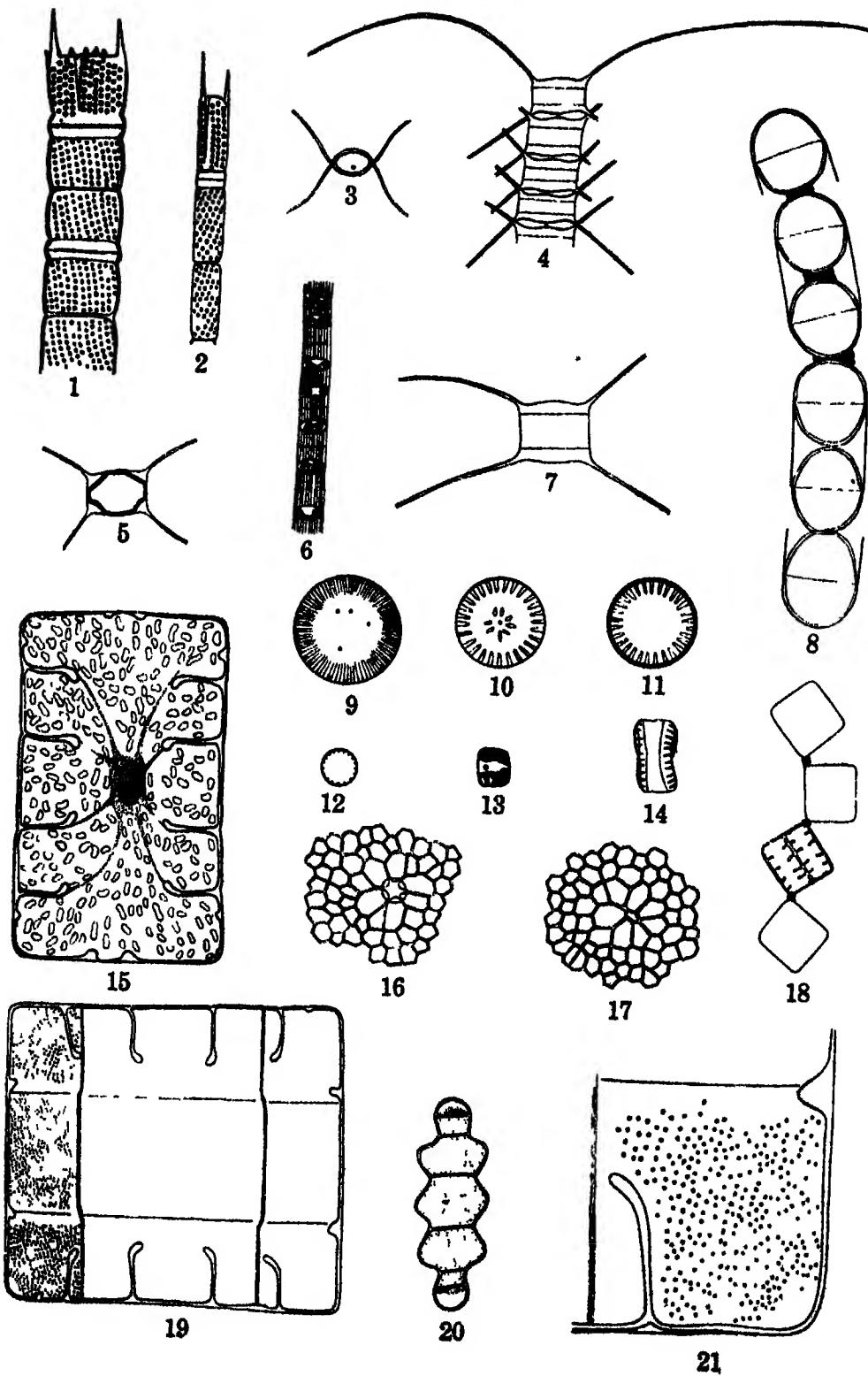
#### *Dimensions —*

Length of the valve	95-148 $\mu$
Breadth of the valve in the central part	35-40 $\mu$
Rows of punctæ in radial rows	10 in 10 $\mu$

*Habitat* — Fresh water Agri - Hort Gardens, Madras (!)

This is an epiphyte on *Pithophora* and *Cladophora* occurring in plenty adorning the algal filaments like festoons. It is found almost throughout the year in one particular pond.

It agrees with the type quite well.



## B Order PENNALES

## I Suborder ARAPHIDINEAE

## (1) Family FRAGILARIACEAE

## (a) Subfamily Tabellarioideae

Genus *Tabellaria* Ehrenberg, C G , 184012 *Tabellaria fenestrata* (Lyngbye) Kütz

(Figs 29, 35, 41)

Smith, W. *Syn Brit Diat*, Vol II, 1858, p 46, pl XLIII, fig 317. De Toni, *Syll. Alg.*, Vol II, part 1, 1891, p 743. Van Heurck, *Traité des Diatomées*, 1899, p 356, pl 11, fig 477. Röver, *Syn N Am Diat*, 1920, p 151. Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 122. fig 99. Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lieff 1-4, 1931-32, p 26, fig 554

Frustules rectangular in girdle view, united at the corners by gelatinous cushions to form zig-zag chains Septa straight, two at each end, extending nearly to the centre Valves linear, elongated, inflated in the middle and at the ends

## Dimensions —

Length	71-85 $\mu$
Breadth	7-8 $\mu$

Habitat — Fresh water stream, Pykara, leg , T Ekambaram

- FIG 1 --- *Melosira granulata* (Ehr ) Ralfs  $\times 1000$   
 FIG 2 — *Melosira granulata* (Ehr ) Ralfs var. *angustissima* Müll  $\times 1000$   
 FIG 3 --- *Charoceros orientalis* Schiller Cell in valve view  $\times 700$   
 FIG 4 — *Charoceros orientalis* Schiller A portion of the chain  $\times 700$   
 FIG 5 -- *Charoceros orientalis* Schiller Cell with a resting spore  $\times 700$ .  
 FIG 6 --- *Skeletonema costatum* (Grev ) Cleve  $\times 800$ .  
 FIG 7.— *Charoceros orientalis* Schiller Beginning cell of a chain  $\times 800$   
 FIG 8 — *Melosira dubia* Kütz  $\times 700$   
 FIG 9 — *Cyclotella Kützingiana* Thwaites.  $\times 1000$   
 FIG 10 — *Cyclotella stelligera* Cl u Grun  $\times 1600$   
 FIG 11 — *Cyclotella Meneghiniana* Kütz Valve view  $\times 1000$   
 FIG 12 — *Thalassionma marginata* sp nov Valve view.  $\times 1600$   
 FIG 13 — *Thalassionma marginata* sp nov Girdle view showing the chloroplasts and the small nucleus  $\times 1600$   
 FIG 14 — *Cyclotella Meneghiniana* Kütz Girdle view.  $\times 1000$ .  
 FIG 15 — *Terpsina musica* Ehr Cell with chloroplasts and nucleus.  $\times 500$   
 FIG 16 — *Coccinadiiscus Granii* Gough Central portion on one side of the valve showing a nodule-like thickening  $\times 1600$   
 FIG 17 — *Coccinadiiscus Granii* Gough. Central portion on the other side of the valve.  $\times 1600$   
 FIG 18 — *Terpsina musica* Ehr Cells united in a zig-zag chain.  $\times 85$   
 FIG. 19.— *Terpsina musica* Ehr Cell in girdle view  $\times 800$ .  
 FIG. 20.— *Terpsina musica* Ehr Cell in valve view.  $\times 850$ .  
 FIG. 21.— *Terpsina musica* Ehr A part of the girdle view magnified.  $\times 1600$

The frustules of this diatom were found at the mouth of the Adyar estuary in brackish water. No living specimens were found in the region. Since this is a fresh-water form, it is evidently brought down from the upper reaches of the river where the water is fresh and not saltish at all.

It agrees with the type in all respects

13 *Tabellaria flocculosa* (Roth) Kütz

(Figs 23, 24)

Smith, W., *Syn Brit Diat.*, Vol II, 1856, pl 45, pl XIIII, fig 316, De Toni, *Syll Aly.*, Vol II, part 1, 1891, p 714, Van Heurck, *Traité des Diatomées*, 1899 p 357, pl 11, fig 478, Schönfeldt, Pascher's *Süßwasser-Flora*, Hft 10, 1913, p. 27, fig 32, Bovet, *Syn N Am Diat.*, 1926, p 152; Hustede, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 128, fig 101, Hustede, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1-4, 1931-42, p 28, fig 558

Frustules quadrangular with from 4 to 8 septa, incurved at each end, and alternating with those of the opposite end. Valves linear with median inflation larger than the terminal.

*Dimensions* —

Length	.	.	20-24 $\mu$
Breadth	.	.	8-8.3 $\mu$
Striae	..	.	15 in 10 $\mu$

*Habitat* — Fresh water Road side ditch, Kodaikanal, Pulneys, leg,  
K S Srinivasan Fresh-water stream, Masingudi, Ootacamund, leg,  
T Ekambaram Fresh-water stream, Pykara, leg, T Ekambaram

The specimens observed are wider in the middle of the valve agreeing with the figure given by Van Heurck (*op cit*, pl 11, fig 478)

(b) Subfamily Fragilarioideae

Genus *Fragilaria* Lyngbye, 1819

14 *Fragilaria intermedia* Grun var *robusta* var nov

(Figs 27, 42)

Frustules in girdle view linear, rectangular, united together to form long bands. Valves linear with parallel sides and gradually tapering ends. Ends slightly capitate. Striae coarse and distinct and on one side absent in the middle region and therefore with a unilateral central area.

*Dimensions* —

Length	..	.	72-140 $\mu$
Breadth	.	..	5-8 $\mu$
Striae	..	..	11-12 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, Trichinopoly, leg., M. O. P. Iyengar

This form shows some resemblance to *Fragilaria virescens* Ralfs (Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 162, Fig. 672) in its size and to some extent to *Fragilaria capucina* Desmazières (*op. cit.*, p. 144, fig. 659, a-e) in the nature of the central area. But in the girdle view the frustules do not show the white hyaline band in the middle characteristic of *F. capucina*. The striae are coarser and far apart in the Vaiyampatti specimens than in *F. virescens*. This form resembles *Fragilaria intermedia* Grun. (*op. cit.*, p. 152, fig. 660) somewhat in the slightly capitate poles, the unilateral central area and in the nature and number of the striae.

The Vaiyampatti form is by far larger than *F. intermedia* and unlike the latter has parallel sides.

### 15 *Fragilaria brevistriata* Grun, forma *elongata* f. nov

(Figs. 25, 26)

Frustules in girdle view linear, rectangular, forming small bands. Valves linear lanceolate with rounded ends. Striae very short and marginal. Pseudoraphe broad.

*Dimensions* —

Length	30-41 $\mu$
Breadth	3-4.5 $\mu$
Striae	12-14 in 10 $\mu$

*Habitat* — Fresh water pond, Agri-Hort. Gardens, Madras (!).

The form agrees in all respects with the type but differs from it in being very much longer. The Madras form has a length of 30-41  $\mu$  while the type is only 12-28  $\mu$  long.

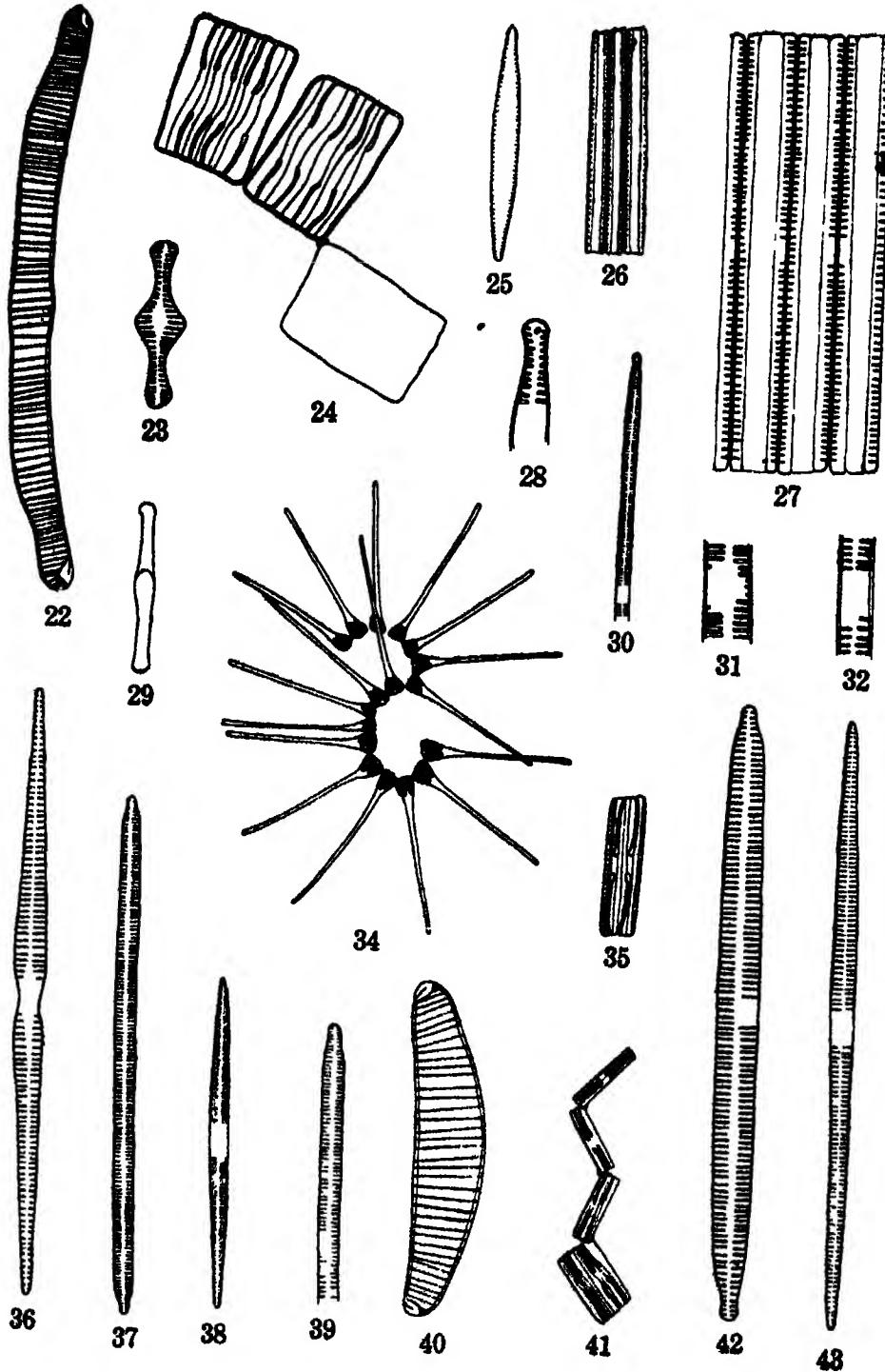
Genus *Synedra* Ehrenberg, C.G., 1830

### 16 *Synedra ulna* (Nitzsch) Ehr

(Figs. 37, 39, 43).

De Toni, *Syll. Alg.*, Vol. II, part 1, 1891, p. 653, Van Heurck, *Traité des Diato* *mées*, 1899, p. 310, pl. 10, fig. 409, Boyer, *Syn. N. Am. Diat.* 1926, p. 198, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1890, p. 151, figs. 158-59; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32 p. 195, fig. 691 A, a-c.

Frustules in girdle view linear, somewhat broadened at the ends. Valves linear to linear lanceolate gradually tapering or tapering only near the ends;



ends rounded Pseudoraphe narrow, linear Central area rounded or rectangular Striae coarse

*Dimensions* —

Length	80-137 $\mu$
Breadth	3.5-7 $\mu$
Striae	10-12 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, near Trichinopoly, leg., M O P Iyengar Red Hills Lake, Madras, leg S V Ganapati Fresh water pond, Presidency College Garden, Madras (!) Fresh water ponds, Agric-Hort Gardens, Madras (!)

The specimens observed agree with the type quite well

- 17 *Synedra ulna* (Nitzsch) Ehr, var *Oxyrhynchus* (Kutz) Van Heurck (Fig. 38)

Van Heurck, *Traité des Diatomées*, 1899 p 311 pl 10, fig 418 Hustedt, Fr., Pacher's *Süsswasser-Flora*, Heft. 10, 1930, p 152 fig 160, Hustedt, Fl., Rabenhorst's *Kryptogamen-Flora* Bd VII, Teil 2 Laef 1-4, 1931-32 p 198, fig 691 B

Frustules below 100  $\mu$  in length, delicately striated and the striae closer

*Dimensions* —

Length	60-90 $\mu$
Breadth	5 $\mu$
Striae	14-16 in 10 $\mu$

FIG. 22.—*Eunotia pertinalis* (Dillw ? Kütz) Rabh var *gibbulosa* var nov  $\times 800$

FIG. 23.—*Tabellaria flocculosa* (Roth) Kütz Cells in valve view  $\times 1100$ .

FIG. 24.—*Tabellaria flocculosa* (Roth) Kütz Cells in a chain  $\times 1100$

FIGS. 25-26.—*Fragilaria brevistriata* Grun f *elongata* f nov  $\times 1000$

FIG. 27.—*Fragilaria intermedia* Grun var *robusta* var nov Cells in a band  $\times 800$

FIG. 28.—*Synedra ulna* (Nitzsch) Ehr var *amphirhynchus* (Ehr) Grun End portion showing the mucilage pore.  $\times 1000$

FIG. 29.—*Tabellaria fenestrata* (Lyng.) Kütz A cell in valve view showing the septa  $\times 325$

FIG. 30.—*Synedra ulna* (Nitz.) Ehr var *amphirhynchus* (Ehr) Grun  $\times 500$

FIGS. 31-32.—*Synedra ulna* (Nitz.) Ehr var *amphirhynchus* (Ehr) Grun Middle portion of the valve showing the variations in the striae.  $\times 1000$

FIG. 34.—*Asterionella japonica* Clove spiral colony, cells with chloroplasts  $\times 250$ .

FIG. 35.—*Tabellaria fenestrata* (Lyng.) Kütz A cell in girdle view  $\times 325$

FIG. 36.—*Synedra ulna* (Nitz.) Ehr var *constricta* var nov  $\times 1000$

FIG. 37.—*Synedra ulna* (Nitz.) Ehr  $\times 700$

FIG. 38.—*Synedra ulna* (Nitz.) Ehr var *oxyrhynchus* (Kütz) Van Heurck  $\times 700$ .

FIG. 39.—*Synedra ulna* (Nitz.) Ehr  $\times 700$

FIG. 40.—*Eunotia monodon* Ehr  $\times 1500$

FIG. 41.—*Tabellaria fenestrata* (Lyngb.) Kütz Cells connected in a zig zag chain.  $\times 100$

FIG. 42.—*Fragilaria intermedia* Grun var *robusta* var. nov  $\times 1000$

FIG. 43.—*Synedra ulna* (Nitz.) Ehr.  $\times 800$ .

*Habitat* — Fresh water pond, Presidency College Garden, Madras (!)  
This form was found attached to some debris near the edge of the pond

18 *Synedra ulna* (Nitzsch) Ehr, var *amphirhynchus* (Ehr) Grun  
(Figs 28, 30, 31, 32)

Schönenfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 39, Hustedt, Fr.  
Pascher's *Süßwasser Flora*, Heft 10, 1930, p 151, fig 167, Hustedt, Fr., Rabenhorst's  
*Kryptogamen Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 200, fig 691 A, e

Valves lanceolate, broad nearly to the end where it suddenly constricts to form capitate ends

*Dimensions* —

Length	.	130-240 $\mu$
Breadth		5-7 $\mu$
Striae		10-12 in 10 $\mu$

*Habitat* — Fresh water stream, Varyampatti, near Trichinopoly, leg.  
M O P Iyengar Pond inside Botanical Gardens, Ootacamund, leg.  
T Ekambaram Fresh water stream, Glen Morgan, Pykara, leg., T Ekambaram Fresh water pond, Presidency College Garden, Madras (!)

The central area varies widely. The striae are completely absent in the central area or only one striation projecting in the central area or the striae shorter on one side and absent on the other

19 *Synedra ulna* (Nitzsch) Ehr, var *constricta* var nov  
(Fig 36)

Valves linear lanceolate, strongly constricted in the middle, the segments gradually tapering towards the ends. Ends rounded. Pseudoraphe narrow, linear. Central area broad, striae absent. Striations distinct

*Dimensions* —

Length	..	84-96 $\mu$
Breadth in the middle	.	3-3.5 $\mu$
Breadth at the broadest portion of the segment	..	4-5 $\mu$
Striae		10-12 in 10 $\mu$

*Habitat* — Fresh water Red Hills Lake, Madras, leg., S V Ganapati.

This form was found along with *Synedra ulna* (Nitzsch) Ehr and *Cymbella Hustedtii* Krasske

In *S. ulna* var *impressa* Hust (Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 199, fig. 691, A 1) sides

are slightly concave and the ends wedge-shaped and the form also seems to be smaller whereas the present form has a deep constriction in the middle with the segments having tapering sides and the form is also larger

Genus *Asterionella* Hassal, 1855

20 *Asterionella japonica* Cleve

(Fig 34)

Gian, H H, *Nordisches Plankton Botanischer Teil*, Bd VIII, 1908, p XIX 118, fig 160, Lebouf Marie, V, *Planktonic Diatoms of Northern Seas*, 1930, p 106, fig 155; Hustadt, Fr, Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 254, fig 734

Frustules forming spiral colonies, linear, narrow with parallel sides and broadened at the base Chromatophores plate-like, two in the broadened base

*Dimensions* —

Length	74-100 $\mu$
Breadth at the base	8-12 $\mu$

*Habitat* — Marine River mouth Cooum, Madras (!) The fine delicate transverse striae recorded by other workers could not be observed in my material even with a very high magnification

II Suborder RAPHIDIOIDINAE

(1) Family EUNOTIACAE

(a) Subfamily Eunotioideae

Genus *Eunotia* Ehrenberg, C G, 1837

21 *Eunotia pectinalis* (Dillw ? Kutz )

Rabenhorst var *gibbosus* var nov

(Fig 22)

Valves linear Dorsal side slightly tumid in the middle Ventral side slightly concave and gibbous in the middle Near the end slightly constricted on the dorsal side but not capitate Ends rounded Striations coarse and clear

*Dimensions* —

Length	.	42-120 $\mu$
Breadth	..	5-8 $\mu$
Striae	.	7-11 in 10 $\mu$

*Habitat* — Fresh water Pools near Elliot beach, Madras, leg , M O P Iyengar

This form was found as a brownish scum inside the water on the dissected leaves of *Limnophila gratoeoides*. They are united to each other by thin valves to form long bands.

This form is in all respects identical with the figure given by Hustedt in Pascher's *Süsswasser-Flora*, Heft, 10, 1930, p 182, fig 241. In his later work (Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 297), he gives two entirely different figures (figs 763, b and c) for the variety *ventralis* (Ehr.) Hust and his fig 241 of the earlier work does not find a place in his later work. The present alga, in possessing a dorsal swelling in the middle, does not agree with the figure of *E. ventricosa* Ehr. var. *elongata* Grunow (Rabenhorst's *Beitr. Kennin.*, Alg 2, 1865, p 4, Tafel 1, fig 4) which Hustedt considers as a synonym of *Eunotia pectinalis* var. *ventralis*.

This appears in a way somewhat distantly similar to var. *undulata*. In a way this could be considered as var. *undulata* with only a single undulation in the middle of the dorsal region. It forms a sort of a transition between var. *ventralis* and var. *undulata*. Moreover, this form does not show any constriction on either side of the middle swelling on the ventral side of the valve nor the club-shaped halves as described and figured by Hustedt (Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil, 2, p 297, fig 763 b and c).

## 22 *Eunotia monodon* Ehr

(Fig 40)

Smith, W., *Syn. Brit. Diat.*, Vol I, 1858, p 16, pl II, fig 16, Schönfeldt, Pascher's *Süsswasser-Flora*, Heft 10, 1913, p 45, fig. 73, Boyer, *Syn. N. Am. Diat.*, 1927, p 221; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 185, fig 254, Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p. 305, fig. 772 a, b.

Valves arcuate with the dorsal side well bent and gradually narrowing towards the ends, ends rounded. Striations coarse, slightly narrower near the ends.

### *Dimensions* —

Length	.	.	26-70 $\mu$
Breadth	.	.	7-11 $\mu$
Striae	.	.	8-10 in 10 $\mu$

*Habitat* — Fresh water Pools near Elliot beach, Madras, leg., M. O P Iyengar Presidency College Garden pond, Madras, leg., Miss John, Agri-Hort Gardens pond, Madras (!) Fresh water pond, Adyar, Madras (!)

This seems to be a narrower form, the maximum breadth reached being equal to the minimum of the type.

23 *Eunotia pseudolunaris* sp nov

(Figs 53, 61)

Valves linear, slender, arcuate with parallel sides Ends rounded. End nodules small Raphe in the valvular plane with a line-like appendage beginning from the end of the raphe and going backwards parallel to the apical axis Raphe very small, comma-shaped Striae fine and clear

*Dimensions* —

Length	68-102 $\mu$
Breadth	3 5 4 $\mu$
Striae	14-15 in 10 $\mu$

*Habitat* — Fresh water Periyar Lake, Travancore, leg, B Sundararaj from the stomach contents of a fish

This form at first sight looks like *Eun lunaris* (Ehr) Grun, the dimensions agreeing very well with the type. But on closer examination, with a higher magnification there is a line-like appendage beginning from the end of the raphe and going backwards parallel to the apical axis, which resembles that of *Eun flexuosa* (Breb) Kütz and *Eun pseudopectinalis* Hust. The present form has got neither a capitate end characteristic of *Eun flexuosa* nor the sudden tapering near the end, characteristic of *Eun pseudopectinalis*. But for the presence of the line-like appendage at the end of the raphe which can be observed only under a very high magnification, and the smooth nature of the ends of the valve without even the slightest depression just below the poles, this form resembles *Eun lunaris* (Ehr) Grun in all other respects. Hustedt in Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 266, classifies *Eunotia* according to the presence or absence of the line-like appendage. Only two forms have been recorded so far having this appendage, viz., *Eun flexuosa* and *Eun pseudolunaris*. The present form does not resemble either of these.

## III Suborder MONORAPHIDINEAE

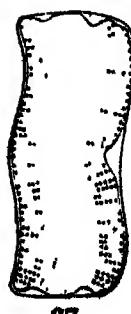
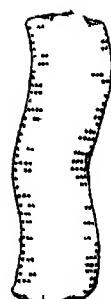
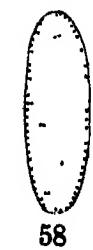
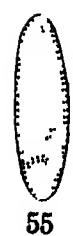
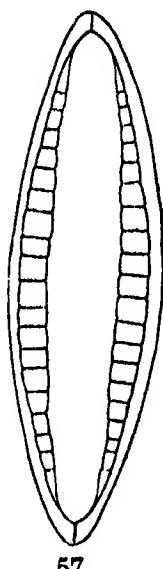
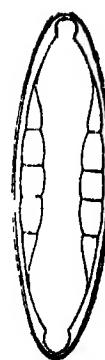
## (1) Family ACHNANTHACEAE

## (a) Subfamily Coccconeoidae

Genus *Cocconeis* Ehrenberg, 183821 *Cocconeis placentula* Ehr var *euglypta* (Ehr) Cleve

(Figs 64, 65, 66)

Cleve, K. S. Vet.-Akad Handl, part 2, Bd 27, No 3, 1895, p 170, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 190, fig. 261; Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd. VII, Teil 2, Lief 1-4, 1931-32, p 349, fig. 802 c.



Valves broadly elliptical, the two valves being similar in outline but dissimilar in punctuation. Hypotheca with a raphe and a distinct central nodule. Punctæ fine, in radial rows. The margin of the valve separated from the central part by a hyaline narrow portion. Epitheca with the pseudoraphe with longitudinal hyaline wavy lines as a result of the transverse striations being composed of short thick lines.

*Dimensions* —

Length	14–28 $\mu$
Breadth	9–15 $\mu$
Striae on the epitheca	18–19 in 10 $\mu$

*Habitat* — Fresh and slightly brackish waters. Common Fresh water stream, Vaiyampatti, near Trichinopoly, leg., M O P Iyengar Stream, Kodaikanal, Pulney, as scum near the water edge along with other diatoms, leg., K S Srinivasan. Fresh water ponds and pools, Madras (!) as epiphyte on *Cladophora* and *Rhzoclonium*.

The forms are variable in outline from more or less rounded to fairly elongated.

(b) Subfamily Achnanthoideæ

Genus *Achnanthes* Bory, 1822

25 *Achnanthes Hauckiana* Grun

(Figs. 50, 51, 56)

De Toni, *Syll. Alg.*, Vol II, part 1, 1891, p 481, Boyer, *Syn N Am Diat.*, 1927, p 237, Hustadt, Fr. Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 202, fig 290, Hustadt, Fr., Rabenhorst's *Kryptogamen Flora*, Bd VII, Teil 2, Taf 1 t, 1931–32, p. 488, fig 834

Figs. 44–45.—*Mastogloia exigua* Lewis f. *brevirostris* f. nov.  $\times 1000$

Figs. 46–48.—*Achnanthes coarctata* Bréb var. *parallello* var. nov

FIG. 49.—*Mastogloia dolosa* sp. nov.  $\times 1000$

Figs. 50–51.—*Achnanthes Hauckiana* Grun.  $\times 1000$

FIG. 52.—*Achnanthes inflata* Kütz.  $\times 800$ .

FIG. 53.—*Eunotia pseudolunararia* sp. nov. End portion showing the raphe and the line like appendage.  $\times 1000$

FIG. 54.—*Achnanthes inflata* Kütz. The valve with the pseudoraphe.  $\times 800$

FIG. 55.—*Achnanthes brevipes* Ag. var. *intermedia* (Kütz.) Cleve. A terratological form.  $\times 800$

FIG. 56.—*Achnanthes Hauckiana* Grun.  $\times 1000$

FIG. 57.—*Mastogloia Brauni* Grun. Showing loculi.  $\times 1600$

Figs. 58–59.—*Achnanthes brevipes* Ag. var. *intermedia* (Kütz.) Cleve.  $\times 1100$

FIG. 60.—*Achnanthes brevipes* Ag. var. *intermedia* (Kütz.) Cleve. A terratological form.  $\times 1100$

FIG. 61.—*Eunotia pseudolunararia* sp. nov.  $\times 800$

FIG. 62.—*Mastogloia Brauni* Grun.  $\times 1600$

FIG. 63.—*Achnanthes brevipes* Ag. var. *intermedia* (Kütz.) Cleve. Girdle view.  $\times 1100$

Figs. 64–66.—*Cocconeis placentula* (Ehr.) var. *euglypta* (Ehr.) Cleve.  $\times 1100$ .

FIG. 67.—*Achnanthes inflata* Kütz. Girdle view.  $\times 1100$ .

Valves elliptic lanceolate with slightly truncate ends Pseudoraphe linear lanceolate Raphe thin, thread-like, axial area narrow, central area somewhat broadened Hypotheca with the raphe having clearly radial striae, the striae on the epitheca only slightly radial

*Dimensions* —

Length	18–20 $\mu$
Breadth	. 5–7 $\mu$
Striae	. 12–15 in 10 $\mu$

*Habitat* — Brackish water Plankton of river Cooum, Madras (!)

This form was found here and there in the plankton of the river Cooum It never occurred in abundance Boyer states that this occurs in the hot springs as well as in brackish waters in Canada The specimens agree with the type quite well

Subgenus *Achnanthidium* (Kütz) Heiberg, 1863

26 *Achnanthes coarctata* Breb var *parallella* var nov

(Pl XVII, Fig 1, Figs 46, 47, 48)

Valves linear elliptic with rounded ends and almost parallel middle portion Raphe straight and coarse in the middle Axial area narrow but clear, central area transversely widened, rectangular Striae slightly radial delicately punctate Pseudoraphe narrow, eccentric Frustules in girdle view slightly bent

*Dimensions* —

Length	44–75 $\mu$
Breadth	. . 8–11 $\mu$
Striae	. 12–14 in 10 $\mu$

*Habitat* — Brackish water Cooum estuary, Madras (!), epiphytic on the filaments of *Lyngbia*

This form has got some resemblance to *A. coarctata* (Breb) Grun var *elliptica* Krasske (Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1–4, p 420, fig 872 d, e) But the present form has got more parallel sides and the form itself is narrow and many times longer than broad This is by far a bigger form than the type whose length varies only from 28–40  $\mu$  whereas the present one has a length of 44–75  $\mu$

27 *Achnanthes inflata* (Kütz) Grun

(Figs' 52, 54, 67)

De Toni, *Syll Alg.*, Vol II, part 1, 1891, p. 475; Boyer, *Syn. N. Am. Diat.*, 1927, p 288; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 209, fig. 807,

Hustedt, Fr., Rabenhorst's *Kryptogamen Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 421, fig. 873

Frustules epiphytic Valves linear, bulged in the middle with broadly rounded poles The pseudoraphe is excentric, striæ radial punctate, puncta coarse and clear

*Dimensions* —

Length	..	..	44-50 $\mu$
Breadth			10-14 $\mu$
Striae	..	..	10-12 in 10 $\mu$

*Habitat* — Fresh water Agri-Hort Gardens pond, Madras (!)

This is an epiphytic form found along with *Ach brevipes* Ag var *intermedia* (Kütz) Cleve on *Cladophora* and *Pithophora*. It agrees well with the type

28 *Achnanthes brevipes* Agardh var  
*intermedia* (Kütz) Cleve  
 (Figs 55, 58, 59, 60, 63)

Schönfeldt, Pascher's *Süßwasser Flora*, Heft 10, 1913, p 58, Boyer, *Syn N. Am Dial*, 1927, p 232, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 210, fig. 310, Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Lief 1-4, 1931-32, p 425, figs 877 d, e

Valves linear with rounded poles, constricted in the middle in the hypotheca and the constriction not seen in the epitheca Central area stauroid The pseudoraphe on the epitheca side, very near the margin Rows of punctæ more radial towards the poles, punctæ large and distinct

*Dimensions* —

Length	35-44 $\mu$
Breadth	8-12 $\mu$
Rows of punctæ	9-10 in 10 $\mu$

*Habitat* — Fresh and brackish water Presidency College Garden pond, Madras (!). Agri-Hort Gardens ponds, Madras (!) Fresh water stream, Vaiyampatti, near Trichinopoly, leg. M O P Iyengar River mouth, Cooum, Madras (!). Adyar estuary, Madras (!)

This form is found as an epiphyte on the filaments of *Rhizoclonium*, *Cladophora*, *Pithophora*, *Oedogonium*, *Lyngbia* and *Oscillatoria* in the fresh water ponds They are attached by their valve faces often forming groups containing 2 to 4 individuals This form is often associated with other epiphytic diatoms such as *Cocconeis placentula* Ehr var *euglyptia* (Ehr) Cleve and *Gomphonema lanceolatum* Ehr Near the mouth of the river

Coconut this form is found throughout the year in plenty as a brownish coating on rocks immersed in the water. Many of the filaments of *Chaetomorpha litorea* Harv growing in this place were often fully covered with this diatom. This was found as a straw epiphyte on some *Enteromorpha* plants also in the same place.

Two teratological forms of this diatom were collected from this place which possess normal shape but the punctæ in some portions are irregularly disposed (Figs 55, 60)

#### IV Suborder BIRAPHIDINEÆ

##### (1) Family NAVICULACRÆ

###### (a) Subfamily Naviculoideæ

Genus *Mastogloia* Thwaites, 1856

29 *Mastogloia dolosa* sp nov

(Fig 49)

Valves elliptic lanceolate, subrostrate Axial area narrow Central area big, rectangular, in conjunction with the two longitudinal hyaline furrows form a H-shaped figure. The furrows on either side of the raphe converge and seem to meet at the top. Striations slightly radial and very finely punctate. Loculi of equal size, ending at a distance from the ends.

##### *Dimensions* —

Length	. 44-62 $\mu$
Breadth	14-20 $\mu$
Striae	. 24-26 in 10 $\mu$
Breadth of the loculi	2 $\mu$
No of loculi	4½-5 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (!) Occurs on the moist soil as a brownish film along with *Mastogloia Brauni* Grun

This form at first sight looks like *Mast. Smithi* Thwaites which it resembles in its elliptic lanceolate shape, the rostrate ends and the equal size of its loculi. But it differs from it in having two longitudinal hyaline furrows which together with the central area forms definite H-shaped figure. This H-shaped figure owing to the extremely delicate structure of the striae, is not seen at first but can be seen very clearly under higher magnifications. In having this H-shaped figure it resembles *Mast. pumila* (Grun) Cleve (Hustedt, Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil, 2, p 553, fig 983) but the loculi of *Mast. pumila* are of different sizes, the middle 1 or 2 being bigger and the rest smaller, whereas in the Madras diatom the loculi are more or less

equal in size Again the two longitudinal hyaline furrows in *M. pumila* are quite parallel throughout their length whereas in the Madras diatom the two furrows on either side of the raphe converge and appear to meet towards the ends In this latter respect it resembles *Mast. exilis* Hust (op cit, p 553, fig 985) where the two furrows converge towards each other at the end, but *Mast. exilis* is a much smaller diatom (15-20  $\mu$ ) long and the loculi much smaller in number and confined only to the middle portion of the valve The present form may therefore be considered as a new species which can be placed between *Mast. pumila* and *Mast. exilis*

### 30 *Mastogloia Brauni* Grun

(Figs 57, 62)

Cleve, K. Sv Vet Akad Handl, part 2, Bd 27, No 3, 1895, p 159, Van Heurck, Traité des Diatomées, 1899, p 158, pl 2, fig 58, Skvortzow Jour Bot, Vol 65, 1927, p 104, figs. 3, 4, 6, Hustedt Fr, Paschor's Süßwasser-Flora Heft 10, 1930 p 218, fig 320, Hustedt, Fl, Rabenhorst's Kryptogamen-Flora, Bd VII, Teil 2 Lief 1-4, 1931-32, p 551, fig 982

Valves elliptic lanceolate Axial area narrow Central area big, rectangular The two narrow longitudinal horns together with the central area form a H-shaped figure Striations transverse in the middle, radial towards the ends, punctate, punctæ fine but distinct Loculi bigger in the middle, smaller at the ends

#### Dimensions —

Length	55-76 $\mu$
Breadth	15-18 5 $\mu$
Loculi	4-6 in 10 $\mu$
Striae	18-20 in 10 $\mu$
Breadth of the loculi in the middle	about 2 5 $\mu$
Breadth of the loculi near the poles	about 1 5 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (?) Occurs as a brown film on the moist soil along with *Mastogloia dolosa* sp nov

The punctæ were fine but distinctly seen under high magnification conforming with the figures given by Van Heurck and Skvortzow Hustedt's form seems to have bigger punctæ

### 31 *Mastogloia exigua* Lewis forma *brevirostris* f nov

(Figs 44, 45)

Valves elliptic Raphe straight Axial area narrow Central area square Striations radial Loculi mostly 5 in number, bigger in the middle

and smaller at the ends, bending suddenly inwards and out again before joining with each other at the end of the poles

*Dimensions* —

Length	30-33 $\mu$
Breadth	9-9.5 $\mu$
Striae	21-23 in 10 $\mu$
Breadth of the bigger loculi	2 2-2 5 $\mu$
Breadth of the smaller loculi	1 2 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (!) Found as a greenish film on the mud inside water along with other diatoms

This form agrees in all respects to *Mastogloia exigua* Lewis (Hustedt, Fr., Rabenhorst's *Kryptogamen-Flora*, Bd VII, Teil 2, Leif 1-4, 1931-32, p 569, fig 1003) excepting for the characteristic end portion of the longitudinal septa. The two longitudinal septa before joining together near the ends of the poles bend suddenly inwards and out again, the outline formed by the two septa appearing very much constricted near the poles and then becoming rounded at the ends. This feature was seen in all the specimens observed. Therefore this form may be considered as a new form of *Mastogloia exigua* Lewis.

Genus *Gyrosigma* Hassal, 1845

32 *Gyrosigma balticum* (Ehr.) Rabh

(Figs 71, 72)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 1, Bd. 26, No. 2, 1894, p 118, Boyer, *Syn. N. Am. Diat.*, 1927, p 456, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 224, fig 331

Valves broad, linear, slightly sigmoid. Raphe eccentric and sigmoid. Central area small, oblique. Transverse and longitudinal striations equally distant.

*Dimensions* —

Length	250-300 $\mu$
Breadth	26-32 $\mu$
Longitudinal and transverse striae	11-13 in 10 $\mu$

*Habitat* — Brackish water River mouth Cooum, Madras (!)

This form agrees well with the figure and description given by Hustedt

33 *Gyrosigma distortum* (W. Smith) Cleve

var *Parkeri* Harrison

(Fig 69)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 1, Bd. 26, No. 2, 1894, p. 116; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 224, fig. 385.

Valves lanceolate, slightly sigmoid, with obtuse protracted ends curved in opposite directions Raphe central, sigmoid Transverse striae more distant than longitudinal

*Dimensions* —

Length	91-115 $\mu$
Breadth ..	19-21 $\mu$
Long Striae	23 in 10 $\mu$
Trans Striae	20-21 in 10 $\mu$

*Habitat* — Slightly brackish water Plankton of the upper portion of the river Cooum, Madras (!) Only stray specimens were found here and there

This form agrees with the type quite well

34 *Gyrosigma scalprordes* (Rabh.) Cleve  
var. *erima* (Thwaites) Cleve  
(Fig. 76)

Cleve, K. *Sv. Vet.-Akad. Handl.*, part 1, Bd 26, No 2, 1891, p 118, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 226, fig 399

Valves linear with parallel sides and obliquely rounded ends Raphe straight, nearly central, slightly sigmoid at the ends Transverse striae finely punctate Longitudinal striae very faint

*Dimensions* —

Length	50-55 $\mu$
Breadth	9-10 $\mu$
Trans Striae	24 in 10 $\mu$

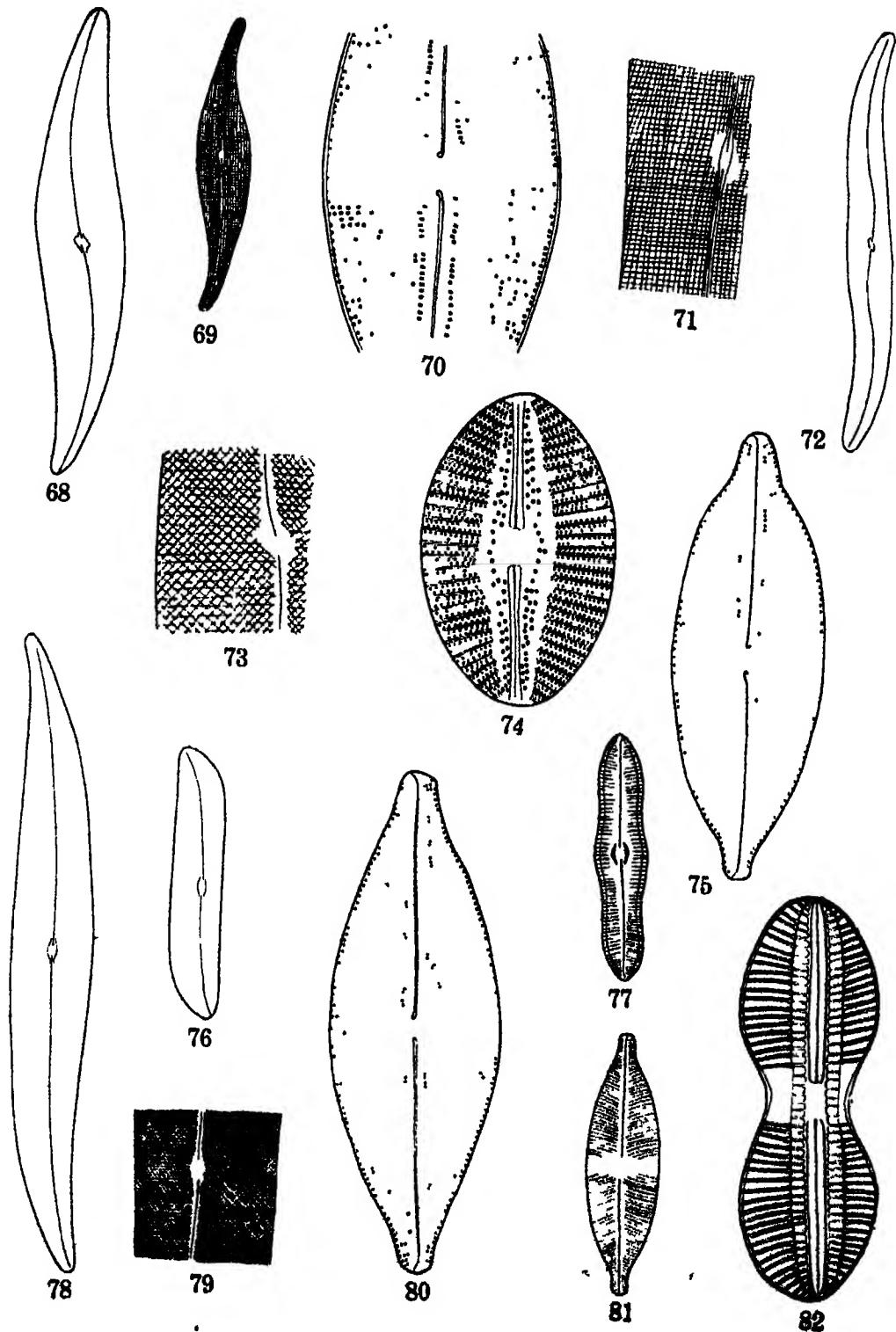
*Habitat* — Brackish water Adyar estuary, Madras (!)

This form agrees with the description of Cleve and Hustedt The longitudinal striae were very faint and were observed only with difficulty under a very high magnification

Genus *Pleurosigma* W. Smith, 1852  
35 *Pleurosigma angulatum* (Quekett) W. Smith  
(Figs. 68, 73)

Smith, W., *Syn. Brit. Diat.*, Vol I, 1853, p 65, pl XXI, fig. 205; Cleve, K. *Sv. Vet.-Akad. Handl.*, part 1, Bd 26, No 2, 1894, p 40, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 228, fig. 342.

Valves slightly sigmoid with acute ends Raphe central, sigmoid Central area small, rhombic Oblique striae at an angle of 60° equidistant with the transverse striae



*Dimensions* —

Length	.	151-160 $\mu$
Breadth	.	29-32 $\mu$
Oblique and transverse striae		20 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (!) Mouth of the river Cooum, Madras (!)

This form agrees with the type quite well

36 *Pleurosigma salinarum* Grun

(Figs 78, 79)

De Toni, *Syll Alq.*, Vol II, part 1, p 1891, p 247, Cleve, *K. Sv Vet.-Akad Handl.*, part 1, Bd 26, No 2, 1894, p 39, Hustedt, Fr., Paster's *Süsswasser-Flora* Heft 10, 1930, p 228, fig 341

Valves linear lanceolate slightly sigmoid with rounded ends Raphe central less sigmoid Central nodule elongated

*Dimensions* —

Length	126-140 $\mu$
Breadth	17-20 $\mu$
Trans striae	23 in 10 $\mu$
Oblique striae	25-27 in 10 $\mu$

*Habitat* — Brackish water River mouth, Cooum, Madras (!) Adyar estuary, Madras (!)

FIG. 68 — *Pleurosigma angulatum* (Quenkott) W Smith  $\times 700$

FIG. 69 — *Gyrosigma distortum* (W Smith) Cleve var *Parkeri* Harrison  $\times 800$

FIG. 70 — *Anomoneus sphaerophora* (Kütz) Pfitzer var *sculpta* (Ehr.) Müll f *indica* f nov Showing the two kinds of punctæ  $\times 1600$

FIG. 71.— *Gyrosigma ballatum* (Ehr.) Rabh Showing the longitudinal and transverse striae  $\times 1100$

FIG. 72 — *Gyrosigma balticum* (Ehr.) Rabh  $\times 250$

FIG. 73 — *Pleurosigma angulatum* (Quenkott) W Smith Showing the striae and the rhombic central area  $\times 1600$

FIG. 74 — *Diploneis subovalis* Cleve  $\times 1600$

FIG. 75.— *Anomoneus sphaerophora* (Kütz) Pfitzer  $\times 1000$

FIG. 76 — *Gyrosigma scalprodes* (Rabh.) Cleve var *eximia* (Thwaites) Cleve  $\times 800$

FIG. 77.— *Culoneus Schumanniana* (Grun) Cleve var *biconstricta* Grun  $\times 1100$

FIG. 78 — *Pleurosigma salinarum* Grun  $\times 700$

FIG. 79 — *Pleurosigma salinarum* Grun Showing the striae  $\times 1100$

FIG. 80 — *Anomoneus sphaerophora* (Kütz) Pfitzer var *sculpta* (Ehr.) Müll f *indica* f nov  $\times 1100$

FIG. 81.— *Stauroneis anceps* Ehr.  $\times 1500$

FIG. 82 — *Diploneis interrupta*  $\times 1600$

This form occurs in plenty on moist soil near the water edge at the mouth of the river Cooum. Sometimes it is found in the plankton also as stray specimens.

Genus *Caloneis* Cleve, 1894

37 *Caloneis Schumanniana* (Grun) Cleve

var *biconstricta* Grun

(Fig 77)

Hustedt, Fr. Pascher's *Süsswasser-Flora*, Heft 10, 1940, p. 210, fig. 370

Frustules constricted near the poles and the middle portion swollen as broad as the polar regions. Ends more or less wedge-shaped, rounded. Axial area narrow, lanceolate. Central area big, elliptic with a lunate marking on each side of the central nodule. Striations slightly radial.

*Dimensions* —

Length	37-43 $\mu$
Breadth	9-11.3 $\mu$
Striae	17 in 10 $\mu$

*Habitat* — Fresh water. As plankton in an irrigation tank at Vandalur Madras, leg. K. G. Veeraraghavan.

In the specimens observed the middle portion was as broad as the polar swellings. In no case was the middle portion broader than the polar portions. The form agrees with the type.

Genus *Diploneis* Ehrenberg, 1840

38 *Diploneis subovalis* Cleve

(Pl XVII, Figs 3 & 4, Fig 74)

Cleve, *K. Sv. Vet.-Akad Handl.*, part 1, Bd 26, No 2, 1894, p. 96, pl I, fig 27, Rich, F., *Trans Roy Soc, S Africa*, Vol XXIV, part III, 1936, p 211, pl X I

Valves elliptical. Central nodule large, rounded. Furrows narrow, closely following the central nodule and its horns. Costæ strong and far apart, alternating with double rows of alveoli.

*Dimensions* —

Length	. . . . .	35-40 $\mu$
Breadth	. . . . .	22-24 $\mu$
Costæ	. . . . .	8-10 in 10 $\mu$
Rows of alveoli	. . . . .	18 in 10 $\mu$

*Habitat* — Fresh water pond, Pykara leg. T. Ekambaram Stream, Coonoor Park, leg. T. Ekambaram

The costæ of this diatom are very characteristic. They are seen clearly below the outer surface of the valve when examined at a slightly lower focus. The costæ are very strong and prominent. They have each a capitate end towards the raphe side. This aspect of the costæ has not been referred to by Cleve (1894, p. 96) in his description of this diatom, nor was I able to find any reference to this structure in any of the available literature here. Plate XVII, Fig. 3, is a photomicrograph of the diatom taken at a higher focus where the double rows of alveoli are clearly seen. But the costæ with the capitate ends are seen only very hazily. But Pl. XVII, Fig. 4, is a photomicrograph of the diatom taken at a slightly lower focus. Here the costæ have come out very well and each of the costæ is seen possessing a prominent capitate end towards raphe side.

The specimens agree with the type in all other respects. It was only a rare form in the collections.

39 *Diplonciscus interrupta* (Kutz.) Cleve  
(Fig. 82)

Cleve, *K. S. Vet.-Akad Handl.*, part 1, Bd. 26, No. 2, 1894, p. 81; Bover, *Syn. N. Am. Diat.*, 1927, p. 348; Carter, N., *Jour. Ecol.*, Vol. XXI, No. 1, 1933, p. 175, figs. 7, 10; Hustedt, Fr., *Pascher's Süßwasser-Flora*, Heft 10, 1930, p. 252, fig. 400.

Valves deeply constricted, the segments elliptical, rounded at the ends. Central nodule elongated, quadrate with parallel horns. Furrows linear, narrow. Costæ strong, usually interrupted in the middle of the valve.

*Dimensions* —

Length	44-60 $\mu$
Breadth in the middle	10-14.5 $\mu$
Breadth at the segments	15-17 $\mu$
Costæ	10-12 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (!).

When examined carefully under very high magnification, the furrow region shows a large number of broad transverse ridges. These transverse ridges are absent in Hustedt's figure but are shown very well in Carter's figure. In the figure given by Hustedt, a row of big punctæ is seen in the furrow region. I was unable to see any such punctæ in my specimens.

Genus *Stauroneis* Ehrenberg, 1843

40 *Stauroneis anceps* Ehr  
(Fig. 81)

Smith, W., *Syn. Brit. Diat.*, Vol. 1, 1853, p. 60, pl. XIX, fig. 100; Cleve, *K. S. Vet.-Akad Handl.*, part 1, Bd. 26, No. 2, 1894, p. 147; Van Heurck, *Traité des Diatomées*, 1899, p. 160, pl. 1, fig. 55; Schönfeldt, *Pascher's Süßwasser-Flora*, Heft 10, 1913,

p. 114, fig 249, Boyer, *Syn N Am. Diat.*, 1927, p. 422; Petersen, J. B., *Bot. of Iceland*, Vol II part 2, 1928, p. 386; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 256, fig 405

Valves linear lanceolate with produced subcapitate ends Stauros reaching the margin Axial area narrow Striae radial, distinctly but finely punctate

*Dimensions --*

Length	44-62 $\mu$
Breadth	12-14 $\mu$
Striae	20-22 in 10 $\mu$

*Habitat* — Fresh water Pools near Elliot beach, Madras, leg., M O P Iyengar (!) Stream, Masingudi, Ootacamund, Nilgiris, leg., T Ekambaram

This agrees very well with the type in all respects

Genus *Anomaeoneis* Pfitzer, 1871

41 *Anomaeoneis sphærophora* (Kütz.) Pfitzer  
(Fig. 75)

Schonfeldt, Pascher's *Süsswasser Flora*, Heft 10, 1913, p. 87, fig. 174, Boyer, *Syn. N. Am. Diat.*, 1927, p. 324, Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 262, fig. 422

Valves elliptic lanceolate with rostrate, capitate ends Axial area broad, linear Central area big, asymmetrical Striations radial, punctate, puncta interrupted by longitudinal, wavy, blank lines

*Dimensions --*

Length	44-58 $\mu$
Breadth	16-20 $\mu$
Striae	15-17 in 10 $\mu$

*Habitat* — Fresh water stream, Varyampatti, near Trichinopoly, leg., M O P Iyengar, Pools near Elliot beach, Madras, leg., M O P Iyengar (!) Slightly brackish water, upper portion of the river Cooum, Madras (!)

This form agrees with the type

42 *Anomaeoneis sphærophora* (Kütz.) Pfitzer  
var *sculpta* (Ehr.) Müller forma *indica* f nov  
(Figs 80, 70)

Valves elliptic lanceolate with only slightly produced but not capitate ends. Axial area broad Central area big Striae radial, punctate, punctæ interrupted There are two sets of striations on the same valve surface. One set is composed of bigger punctæ with an asymmetrical central area and

the other set is composed of finer punctæ which fill up the whole valve surface leaving only a small central area

*Dimensions* —

Length	62-76 $\mu$
Breadth	21-26 $\mu$
Striae	11-15 in 10 $\mu$

*Habitat* — Fresh water pond, Adyar, Madras (!)

This form agrees with *A. sphaerophora* var *sculpta* in all respects, but the central area is asymmetric and on one side the axial area is completely free from the punctæ. But when carefully examined under a very high magnification most of the spaces which appear to be empty show numerous very fine punctæ. These fine punctæ are, however, absent in the axial area.

Genus *Navicula* Bory, 1822

Section *Navicula orthostichæ* Cleve

43 *Navicula cuspidata* Kütz var *conspicua* var nov

(Figs. 83, 88)

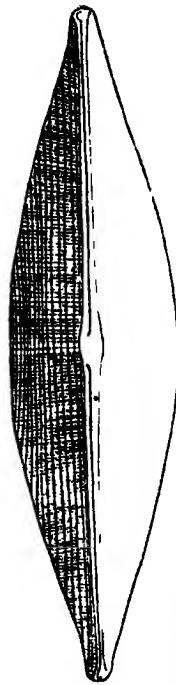
Valves rhombic to elliptic lanceolate with rounded and slightly constricted ends. Axial area narrow, central area slightly broadened. The raphe bent like hooks in the central area. Transverse striations parallel, slightly convergent near the poles. Longitudinal striations coarse, clear and prominent closer towards the margins and wider towards the middle field. Sometimes the longitudinal striations are broken in the middle portion near the central area. The craticular plates characteristic of *Navicula cuspidata* Kütz are also present.

*Dimensions* —

Length	120-144 $\mu$
Breadth	28-35 $\mu$
Trans Striae .	12-15 in 10 $\mu$
Long Striae	8-14 in 10 $\mu$

*Habitat* — Fresh water, Masingudi brook, Ootacamund, Nilgiris, leg. T. Ekambaram. Fresh water pond inside Museum compound, Madras, leg., M. T. Philipose.

This form differs from *Navicula cuspidata* Kütz in having the longitudinal striae closer towards the margins than towards the middle line. These longitudinal striae appear to be very strong. They are only 8-14 in 10  $\mu$  whereas in the type the longitudinal striations are closer (25 in 10  $\mu$ ) than the transverse striations. Besides this, the present form has slight constriction



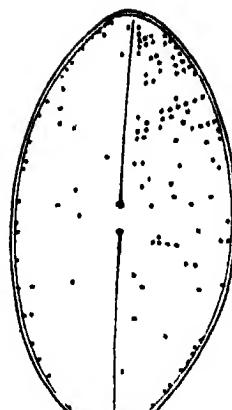
83



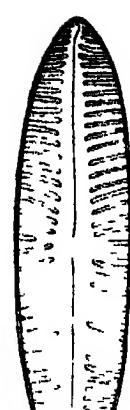
84



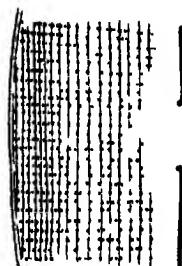
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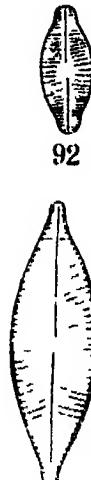
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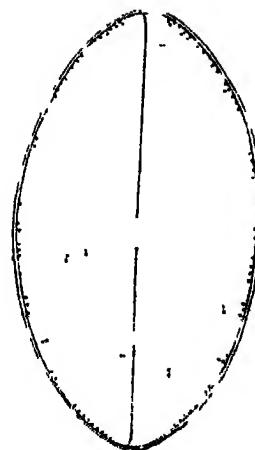
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98

near the poles On these grounds, this form has been created as a new variety of *Navicula cuspidata* Kütz

44 *Navicula cuspidata* Kütz var *ambigua* (Ehr.) Cleve

(Fig. 94)

Clev., *A Sv Vet.-Akad Handl.*, part 1, Bd 26, No 2, 1894, p 110; Boyer, *Syn N Am Dial.*, 1927, p 336; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 268, fig 434

Valves elliptic lanceolate with produced rostrate ends Axial area narrow Central area slightly widened in the middle The transverse striae are slightly radial The longitudinal striae are equally placed

*Dimensions* —

Length	65-77 $\mu$
Breadth	18 5-20 $\mu$
Trans Striae, Long Striae	17 19 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, near Trichinopoly, leg. M O P Iyengar

The produced ends of this form are not so much pronounced as given by Hustedt in Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 268, fig 434

45 *Navicula halophila* (Grun.) Cleve

f *subcapitata* Ostrup

(Fig. 91)

Kolbe, R W, *Planzensforschung*, Heft 7, 1927, p 68, Tafel 1, fig 6; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930 p 269

FIG 83.—*Navicula cuspidata* Kütz var *conspicua* var nov  $\times 700$

FIG 84.—*Navicula gracilis* Ehr.  $\times 1000$

FIG 85.—*Navicula peregrina* (Ehr.) Kütz var *Kefvingensis* (Ehr.) Cleve  $\times 800$

FIG. 86.—*Navicula lacustris* Greg var. *major* var. nov  $\times 1100$

FIG. 87.—*Navicula digitoradiata* (Greg) A. Schmidt  $\times 1100$

FIG. 88.—*Navicula cuspidata* Kütz var *major* var nov. Showing the prominent longitudinal striae and the punctate transverse striae  $\times 1800$ .

FIG. 89.—*Navicula cincta* (Ehr.) Kütz var. *Heufleri* Grun  $\times 1100$

FIG. 90.—*Navicula rostellata* Kütz.  $\times 1000$ .

FIG. 91.—*Navicula halophila* (Grun.) Cleve f *subcapitata* Ostrup  $\times 1500$

FIG. 92.—*Navicula laterostrata* Hust  $\times 1100$

FIG. 93.—*Navicula protracta* Grun.  $\times 1100$ .

FIG. 94.—*Navicula cuspidata* Kütz var. *ambigua* (Ehr.) Cleve  $\times 1000$

FIG. 95.—*Navicula valnarinum* Grun.  $\times 1100$ .

FIG. 96.—*Navicula lyra* Ehr.  $\times 1000$ .

FIG. 97.—*Navicula pigmæa* Kütz  $\times 1000$

FIG. 98.—*Navicula hasta* Pant  $\times 800$ .

Valves lanceolate with slightly produced and capitate ends Axial area narrow, linear, central area slightly widened in the middle Striations parallel and slightly convergent at the ends

*Dimensions* —

Length	32-36 $\mu$
Breadth	8-9 $\mu$
Striae	14-15 in 10 $\mu$

*Habitat* — Brackish water River Cooum, Madras (!)

This form was collected from the littoral region in the upper portion of the river Cootim, occurring in plenty as pure forms without any other diatoms. This occurs in the plankton also sometimes Kolbe (*op. cit.*, p. 68) has collected these forms as pure individuals Mesohalobic form

This form slightly differs from the figure given by Kolbe in its having a somewhat rounded central portion and a less pronounced capitate end

Section *Navicula decipiens* Cleve

46 *Navicula protracta* Grun

(Fig. 93)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 1, Bd. 26, No. 2, 1894, p. 140, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 284, fig. 472

Valves linear with rostrate, truncate ends Axial area very narrow Central area small, slightly widened Striation slightly radial and at the ends parallel, in the middle somewhat coarse

*Dimensions* —

Length	. . . .	20-26 $\mu$
Breadth	. . . .	7 5-8 6 $\mu$
Striae	. . . .	18-19 in 10 $\mu$

*Habitat* — Brackish water Stray in the plankton of river Cooum, Madras (!)

This form agrees with the type quite well

Section *Navicula lineolata* Cleve

47 *Navicula salinarum* Grun

(Fig. 95)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 2, Bd. 27, No. 3, 1895, p. 19; Van Heurck, *Traité des Diatomées*, 1899, p. 178, pl. 8, fig. 108; Boyer, *Syn. N. Am. Diat.*, 1927, p. 383, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 295, fig. 498

Valves elliptic lanceolate with produced subcapitate ends Axial area narrow, central area big, rounded Striae strongly radiate, in the middle longer and shorter, and in the end transverse

*Dimensions* —

Length	.	.	..	35-41 $\mu$
Breadth	.	.		10-12 $\mu$
Striae	.	.		13-14 in 10 $\mu$

*Habitat* — Brackish water Plankton of the river Cooum, Madras (!)

This form never occurred in plenty but only as stray individuals The specimens agree best with the figure given by Van Heurck in the nature of the slightly capitate ends

48 *Navicula rostellata* Kütz

(Fig. 90)

Kützing, *Species Algarum*, 1849, p 75, Itabenhörst, *Flora Europaea Alg.*, 1, 1804, p 200, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 297, fig. 502.

Valves narrow, elliptic lanceolate with short, thin, narrowly produced, rostrate ends Axial area narrow, central area big, rounded Striations delicate radial, and at the ends convergent

*Dimensions* —

Length	.	.	..	38-45 $\mu$
Breadth	.	.	..	9-10 $\mu$
Striae	.	.		10-11 in 10 $\mu$

*Habitat* — Brackish water River Cooum, Madras (!)

This form was often met with in the plankton of the river Cooum Though it did not occur in plenty, it was found fairly in good number It agrees well with the type The striations are extremely fine and were observed only with much difficulty

49 *Navicula cincta* (Ehr.) Kutz

var *Heufleri* Grun

(Fig. 89)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 2, Bd. 27, No 3, 1895, p 10; Van Heurck, *Traité des Diatomées*, 1899, p 178, pl 3, fig. 106; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1918, p. 92; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 298, fig. 511.

Valves linear lanceolate with obtuse ends. Axial area narrow Central area small, broadened Striations radial in the middle and at the end convergent, coarse and distinct The striae are wider apart than in the species

*Dimensions* —

Length	26–32 $\mu$
Breadth	5–6 $\mu$
Striae	10 in 10 $\mu$

*Habitat* — Brackish water River Cooum, Madras (!)

This form was found in the littoral region, on moist soil This form agrees with the type in all respects

50 *Navicula gracilis* Ehr

(Fig 84)

Cleve, *K. Sv. Vet.-Akad Handl.*, part 2, Bd 27, No 3, 1895, p 17, Schönfeldt. Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 90, fig 182, Boyer, *Syn N Am Diat.* 1927, p 285; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 299, fig 514

Valves linear, the middle portion with parallel margins and with obtuse ends Axial area narrow, central area rectangular Striations transverse in the middle and slightly radial at the ends

*Dimensions* —

Length	36–42 $\mu$
Breadth	6–7 5 $\mu$
Striae	11–12 in 10 $\mu$

*Habitat* — Slightly brackish water River Cooum, Madras (!)

This form occurs in the littoral region Not a common form

51 *Navicula peregrina* (Ehr) Kützvar *Kefringensis* (Ehr) Cleve

(Fig 85)

Cleve, *K. Sv. Vet.-Akad Handl.*, part 2, Bd 27, No 3, 1895, p 18, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 300

Valves lanceolate with obtuse ends Axial area distinct, narrow, central area broadened, elliptical Striations coarse, radial and at the ends convergent

*Dimensions* —

Length	40–80 $\mu$
Breadth	12–16 $\mu$
Striae	7–8 in 10 $\mu$

*Habitat* — Brackish water River mouth, Cooum, Madras (!)

The ends are clearly rounded and not slightly truncated as given in the description by Hustedt This form occurred as pure individuals forming a thin yellow film over the moist soil near the river mouth, Cooum.

52. *Navicula digitoradiata* (Greg) A Schmidt  
 (Fig. 87)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 301, fig. 518.

Valves lanceolate with obtuse ends Axial area narrow, central area transversely widened and irregular Striations radial, in the middle alternately shorter and longer and at the end parallel

*Dimensions* —

Length	51-60 $\mu$
Breadth	13-16 $\mu$
Striae	8-9 in 10 $\mu$

*Habitat* — Brackish water River mouth, Cooum, Madras (1)

This form was collected once from the littoral region among other diatoms The specimens show not much alternating shorter and longer striae in the middle region It agrees with the type in all other respects

53. *Navicula laterostrata* Hust  
 (Fig. 92)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 301, fig. 521

Valves elliptic lanceolate with broadly rounded and with more or less capitate ends Axial area very narrow Central area big, rounded Striations delicate slightly radial and closer towards the ends

*Dimensions* —

Length	18-22 $\mu$
Breadth	6-9 $\mu$
Striae in the middle	15 in 10 $\mu$
Striae towards the ends	21-22 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (1)

This form is slightly smaller than the type described by Hustedt The striae are very delicate and were seen only with difficulty

54. *Navicula hasta* Pantoesek  
 (Fig. 98)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 2, Bd. 27, No. 3, 1895, p. 25, Boyer, *Syn N. Am. Dial.*, 1927, p. 399, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 306, fig. 541

Valves lanceolate, gradually tapering from the middle to the subacute ends Axial area narrow, widened slightly in the middle Striations strongly radial, middle few are coarse and slightly wide part

*Dimensions* —

Length	60–80 $\mu$
Breadth	15 $\mu$
Striae	9–10 in 10 $\mu$

*Habitat* — Brackish water River Cooum, Madras (!)

This form occurs on moist soil near the water edge along with other littoral diatoms. Forms that are shorter in length by 10  $\mu$  than the type have been met with

Section *Naviculae punctata* Cleve

55 *Navicula lacustris* Greg var *major* var nov  
(Fig. 86)

Valves broadly elliptical with obtuse rounded ends Axial area narrow, linear, central area large, transversely widened, more or less rectangular. Striations radial, punctate puncta large and round

*Dimensions* —

Length	70–84 $\mu$
Breadth	26–30 $\mu$
Striae	9–10 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras, leg., S. Dorai-swami (!)

This form differs from the type (Gregory, *Quart Jour Micr Sci*, Vol IV, 1856, p 6, pl I, fig 23) in several respects. The present form is a bigger one than the type which is only 35–60  $\mu$  long and 16–20  $\mu$  broad. The type has a linear lanceolate shape and with subrostrate or acute ends (Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 310, fig 555, Cleve, *K Sv Vet-Akad Handl*, Part 2, Bd 27, No 3, 1895, p 44) whereas the Madras form is broadly elliptical with obtuse or nearly rounded ends. The central area is orbicular in the type (*cf* Cleve and Hustedt) whereas in the present form it is transversely expanded and more or less transversely elliptic. Again in the type, the punctæ limiting the axial area are bigger than the other punctæ, but in the present form these are more or less of the same size as the other punctæ.

Section *Naviculae lyrae* Cleve

56 *Navicula lyra* Ehr  
(Fig. 96)

Cleve, *K. Sv. Vet-Akad Handl*, part 2, Bd. 27, No. 3, 1895, p 68; Van Heurck, *Treatise des Diatomées*, 1899, p 202, pl 4, fig. 161; Boyer, *Syn. N. Am. Diat.*, 1927, p. 411.

Valve elliptical with rounded ends Lateral areas linear, narrow, constricted in the middle and slightly divergent at the ends Striae punctate, puncta coarse and clear

*Dimensions* —

Length	52-60 $\mu$
Breadth ..	37 $\mu$
Striae	10-11 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (!)

This form was found as a stray one in a collection of the brown film over the mud containing a number of other brackish water diatoms This agrees very well with the type

57 *Navicula pygmaea* Kutz

(Fig 97)

Kitzing, *Species Algarum*, 1849, p 77, Cleve, *K. Sv. Vet.-Akad. Handl.*, part 2, Bd 27, No 3, 1895, p 65, Van Heurck, *Traité des Diatomées*, 1899, p 203, pl 4, fig 164, Boyer, *Syn V Am Diat*, 1927, p 116 Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 312, fig. 561

Valves hyaline, elliptical with broadly rounded ends Axial area indistinct Lateral areas constricted in the middle and convergent at the ends Striations very delicate

*Dimensions* —

Length ..	23-27 $\mu$
Breadth ..	10-11 $\mu$
Striae about	25 in 10 $\mu$

*Habitat* — Brackish water Plankton of river Cooum, Madras (!)

This is a form that is often met with in the plankton of the river Cooum The structure is very delicate so that a very high magnification is required for deciphering it It agrees with the type

Genus *Pinnularia* Ehrenberg, 1843

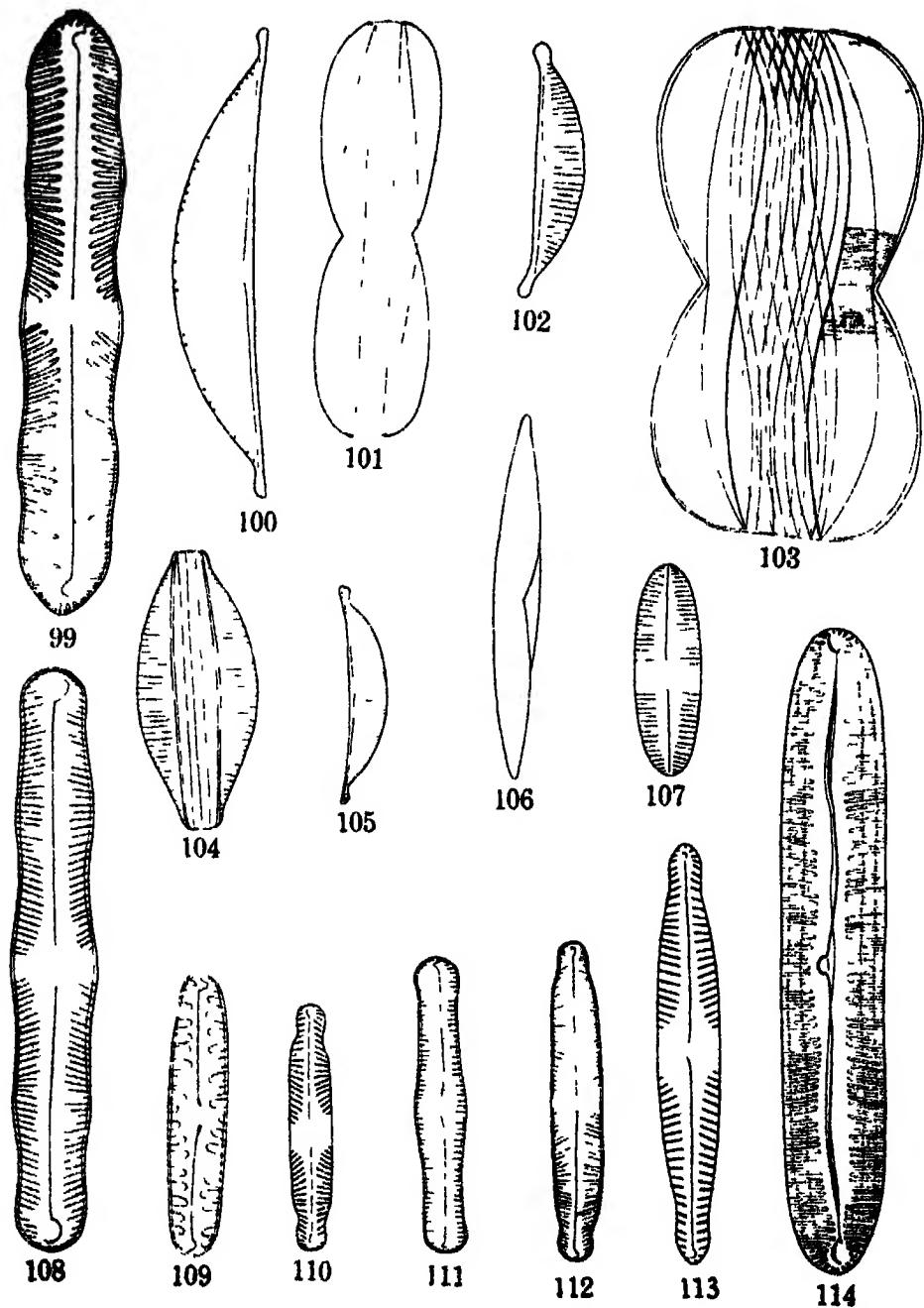
Section *Parallelistriata*

58 *Pinnularia fasciata* (Lagerstedt) Hust

(Fig 107)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 316, fig 569.

Valves linear lanceolate with rounded ends Axial area narrow Lanceolate central area widened into a broad fascia reaching the margin Striations parallel in the middle and slightly radial towards the ends, delicate,



*Dimensions —*

Length	16–21 $\mu$
Breadth	4 5 7 $\mu$
Striae	23–25 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, near Trichinopoly, leg. M O P Iyengar

This differs from Hustedt's species in having slightly radial striations at the ends rather than slightly convergent at the ends. He feels that this species is doubtful of identification since there is a similar species in *Caloneis bacillum* (Grun) Meresch (*op cit*, p 236, fig 360 a). The present form in the nature of the striations and the dimensions agrees with *Caloneis bacillum* (Grun) Meresch. But the longitudinal line close to the margin which is characteristic of the genus *Caloneis* is not clearly seen. Under very high magnification, however, it looks as though there is a faint longitudinal line running close to the edge of the valve, but the line-like appearance may be a false one due to the edge of the valve and is therefore not quite convincing.

*Section Capitalæ**Pinnularia interrupta* W Smith

Smith, W, *Syn Brit Diat*, Vol 1, 1853, p 59, pl XIX, fig 184. Cleve, *K Sv Vet-Akad, Handl.*, part 2, Bd 27, No 3, 1895, p 70, Fritsch, F E, *Ann S Afr Mus*, Vol. IX, part VII, 1918, p 590, figs 40 a-d, Fritsch, F E, and Rich, F, *Trans Roy Soc S Africa*, Vol XI, 1925, p 384, Hustedt, Fr, Pascher's *Süsswasser Flora*, Heft 10, 1930, p 317 fig 573 a b.

This is a very variable species. All the forms present in the various collections showed interruption of the striae at the middle of valve.

FIG 99 — *Pinnularia gibba* Ehr f *undulata* f nov  $\times 1600$

FIG 100 — *Amphora holeatica* Hust  $\times 1100$

FIG 101 — *Tropidoneis lepidoptera*  $\times 800$

FIG 102 — *Amphora coffeiformis* Ag var *africana* Fritsch and Rich  $\times 1600$

FIG 103 — *Amphipora paludosa* W Smith var *subsalsina* Cleve  $\times 1000$

Figs 104-105.— *Amphora coffeiformis* Ag  $\times 1100$

FIG 106.— *Tropidoneis lepidoptera* (Greg) Cleve Valve view  $\times 800$

FIG 107 — *Pinnularia fasciata* (Lagerst.) Hust  $\times 1600$

FIG 108 — *Pinnularia gibba* Ehr f. *subundulata* Mayer  $\times 800$

FIG 109 — *Pinnularia borealis* Ehr  $\times 1100$

FIG 110 — *Pinnularia interrupta* W Smith f *subcapitata* Fritsch  $\times 1100$

FIG. 111.— *Pinnularia acrosphaeria* Breb  $\times 800$

FIG. 112 — *Pinnularia interrupta* W. Smith f *genuina* Fritsch.  $\times 800$

FIG. 113 — *Pinnularia Brauni* (Grun) Cleve var. *amphicephala* (A. Mayrr) Hust. f *subconica* f. nov.  $\times 1600$ .

FIG. 114.— *Pinnularia viridis* (Nitzsch) Ehr.  $\times 800$ .

Fritsch in *Ann S Afr Mus*, Vol IX, Part VII, 1918, p 590, has grouped the different forms according to the nature of the margins, the polar regions and the interruptions of the striae in the middle

59 *Pinnularia interrupta* W Smith f *genuina* Fritsch  
 (Fig 112)

*Pinnularia interrupta* W Smith, W Smith, *Syn. Brit Diat*, Vol I, 1853, p. 59, pl. XIX, fig 184.

Sides of the valves straight and parallel, striations interrupted at the centre of the valve Ends markedly capitate

*Dimensions* —

Length	51-70 $\mu$
Breadth	9-10 5 $\mu$
Striae	12 in 10 $\mu$

*Habitat* — Fresh water pond, Adyar, Madras (!) Very slightly brackish water, river Cooum, Madras (!) From the stomach contents of a fish in Periyar lake, Travancore, leg, B Sundararaj

This form agrees with the description given by Fritsch and the figure given by W Smith and Hustedt (*Pascher's Süsswasser-Flora*, Heft 10, 1930, p 317, fig 573 b)

60 *Pinnularia interrupta* W Smith f *subcapitata* Fritsch  
 (Fig 110)

*Syn. P. subcapitata*, Gregorv. *Quart Jour Micr Sci*, Vol IV, 1856, p 9, pl. 1, fig 30

Sides of the valve straight and parallel Striations interrupted at the centre of the valve Ends not very markedly capitate

*Dimensions* —

Length	..	26.7-36 $\mu$
Breadth		5-7 $\mu$
Striae		10-11 in 10 $\mu$

*Habitat* — Fresh water Pools near Elliot Beach, Madras, leg, M O P Iyengar Agri-Hort Gardens pond, Madras (!)

This form is slightly smaller than f *genuina* Fritsch from the specimens observed The striations are far apart and it agrees with the figure given by Gregory (*op cit*)

61 *Pinnularia Braunii* (Grun.) Clevevar *amphicephala* (A. Mayer) Hust., forma *subconica* f. nov.

(Fig. 113)

Valves linear lanceolate with more or less markedly convex sides. Slightly constricted below the poles and the ends slightly capitate and more or less wedge-shaped. Axial area narrow. Central area widened. Striae interrupted in the middle portion of the valve, radial in the middle and convergent at the ends.

*Dimensions* —

Length	40-43 $\mu$
Breadth	5-5.6 $\mu$
Striae	14 in 10 $\mu$

*Habitat* — Fresh water. Pools near Elliot Beach, Madras, leg., M. O. P. Iyengar (!).

This form comes very near *P. Braunii* var *amphicephala* but differs from it in its ends being not so capitate as in the type variety, but in having only slightly capitate ends and also in the ends being not rounded as in the type but slightly wedge-shaped. The form resembles in all respects the figure *P. interrupta* f. *Braunii* Fritsch (Fritsch, F. E., Ann. S. Afr. Mus., Vol. IX, Part VII, 1918, p. 592, fig. 40 a, b).

*Section Distances*62 *Pinnularia borealis* Ehr

(Fig. 109)

Cleve, K. Sv. Vet.-Akad. Handl., part 2, Bd. 27, No. 3, 1895, p. 80, Van Heurck, Traits' des Diatomées, 1899, p. 170, pl. 2, fig. 77, Schönsfeldt, Pascher's Süsswasser-Flora, Heft 10, 1913, p. 106, fig. 227, Boyer, Syn. N. Am. Diat., 1927, p. 437, Potemn, J. B., Botany of Iceland, Vol. II, part 2, 1928, p. 401, Hustedt, Fr., Pascher's Süsswasser-Flora, Heft 10, 1930, p. 320, fig. 597.

Valves linear elliptical with broadly rounded ends. Axial area somewhat widened in the middle. Raphe thread-like, with strongly hooked terminal fissures. Striations coarse, slightly radial in the middle.

*Dimensions* —

Length	40-55 $\mu$
Breadth	.. 9-11 $\mu$
Striae	4-5 in 10 $\mu$

*Habitat* — On a decaying fern leaf in water. Fresh water stream, Bearshola, Kodaikanal, Pulneys, leg., K. S. Srinivasan.

This form agrees with the type, only the maximum length in the material is much below that of the species given by Hustedt (28-110  $\mu$  long and 8-18  $\mu$  broad)

It was a rare form in the collection

*Section Tabellaria*

63 *Pinnularia gibba* Ehr f *subundulata* Mayer  
(Fig 108)

Hustedt, Fr. Pischel's *Süsswasser-Flora*, Heft 10, 1930 p 327, fig 601

Valves linear with slightly wavy margins and gradually tapering from the middle to the subcapitate ends Ends rounded or slightly wedge-shaped Axial area of variable breadth, dilated in the middle Striations radial in the middle, parallel above and convergent at the ends Striae interrupted at the middle portion

*Dimensions* —

Length	100-127 $\mu$
Breadth	12-14 $\mu$
Striae	9 11 in 10 $\mu$

*Habitat* — Fresh water As plankton of an irrigation tank at Vandalur near Madras, leg , K G Veeraraghavan Only few specimens were found

64 *Pinnularia gibba* Ehr f *undulata* f nov  
(Fig 99)

The undulations of the valve margins are more pronounced There is only a very slight decrease in the breadth of the valve towards the ends The ends are strongly wedge-shaped

*Dimensions* —

Length	58-70 $\mu$
Breadth	9-10 5 $\mu$
Striae	9-10 in 10 $\mu$

*Habitat* — Fresh water As plankton of an irrigation tank at Vandalur, Madras, leg , K G Veeraraghavan

This form in the wavy outline resembles *P. gibba* f *subundulata* but differs from it in the undulations being more pronounced and the ends of the valves being not rounded but more or less wedge-shaped Again it is a very much smaller form than *P. gibba* f *subundulata* both in length and in breadth. *P. gibba* f *subundulata* is 100-127  $\mu$  long and 12-14  $\mu$  broad whereas the present form is only 58-70  $\mu$  long and 9-10 5  $\mu$  broad

Section *Brevistriata*65 *Pinnularia acrosphaera* Brebisson

(Fig 111)

Cleve, K. *Sv Vet-Akad Handl.*, part 2, Bd 27, No 9, 1895, p 86, Schönsfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1918, p 108, fig 228, Boyer, *Syn N Am Diat*, 1927 p 441, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 330, fig 610

Valves linear, gibbous in the middle and at the ends Axial area broad, linear Median area punctate Striations nearly parallel and slightly radial at the ends

*Dimensions* —

Length	38-62 $\mu$
Breadth	8-12 $\mu$
Striae	9-12 in 10 $\mu$

*Habitat* — Fresh water brook, Masingudi, Ootacamund, Nilgiris, leg., T Ekambaram, Agri-Hort Gardens pond, Madras (!) Presidency College garden pond, Madras (!)

In a few specimens the punctæ in the axial area were a bit difficult to decipher, though in all the other cases they were quite clear. In the present form the middle portion of the valve is always rather more swollen than the form figured in Hustedt. This form was found here and there among other diatoms in the collections.

Section *Complexa*66 *Pinnularia viridis* (Nitzsch) Ehr

(Fig 114)

Boyer, *Syn N Am Diat*, 1927, p 440, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 331, fig 617 a

Valves linear with slightly convex margins and rounded ends Raphe complex Axial area narrow, slightly widened in the middle The central knot is clearly seen and is slightly shifted to one side Stria coarse, slightly radial in the middle and convergent at the ends The longitudinal band is present

*Dimensions* —

Length	93-136 $\mu$
Breadth	18-20 $\mu$
Striae	8-9 in 10 $\mu$

*Habitat* — Fresh water Pools near Elliot Beach, Madras, leg., M O P Tyengar (!)

In the specimens observed the two margins of the valve appear slightly more parallel in the middle region than in the type. In this respect it resembles *P. viridis* var. *sudetica*, but the longitudinal bands are quite well seen instead of its being not clear as in var. *sudetica*. The Madras form has also got a resemblance to *P. streptoraphe* Cleve (Hustedt, Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 337, fig. 620). But it is a bigger form (180–260  $\mu$  long) and also the raphe is more complex.

(b) Subfamily Amphiproroidea

Genus *Amphiprora* Ehrenberg, 1843

67 *Amphiprora paludosa* W. Smith

var. *subsalina* Cleve

(Fig. 103)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 1, Bd. 26, No. 2, 1891, p. 11, Hustedt, F1.,  
Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 340

Frustules membranaceous. In girdle view broad with truncate ends. Median line sigmoid. Junction line with a large sinus. Frustule strongly constricted in the middle.

*Dimensions* —

Length	68–84 $\mu$
Striae	23 in 10 $\mu$

*Habitat* — Brackish water. On moist soil at the banks of the river Cooum (')

The extremely delicate striae were seen under very high magnification. The striae are finely punctate.

Genus *Iropidoneis* Cleve, 1891

68 *Iropidoneis lepidoptera* (Greg.) Cleve

(Figs. 101, 106)

Cleve, *K. Sv. Vet.-Akad. Handl.*, part 1, Bd. 26, No. 2, 1891, p. 25, Boyer, *Syn. N. Am. Diat.*, 1927, p. 480

*Amphiprora [Orthotropis] lepidoptera* (Greg.) Cleve; Van Heurck, *Trakte' des Dialektes*, 1899, p. 268, p. 5, fig. 287

Frustules elongated, more or less rectangular, strongly constricted in the middle. Valves linear lanceolate with acute ends, central area indistinct, small. Wing unilateral, projecting above the central nodule. Transverse striae finely punctate.

*Dimensions* —

Length	85-120 $\mu$
Breadth	15-25 $\mu$
Striae	about 23 in 10 $\mu$

*Habitat* — Brackish water Cooum estuary, Madras (!) Adyar estuary, Madras (!)

This form occurs in the littoral regions, on the moist soil among other diatoms, forming a thin brown film

(c) Subfamily Gomphocymbelloidea

Genus *Amphora* Ehrenberg, 1840

Section *Halampora* Cleve

69 *Amphora holsatica* Hust

(Fig 100)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 345, fig. 633

Frustules lunate with slightly rounded poles The dorsal side is convex and the ventral side straight Raphe straight, parallel to the ventral margin Axial area on the dorsal side very narrow Transverse striae radial, punctate, puncta big

*Dimensions* —

Length	38 5-50 $\mu$
Breadth	10 7-18 $\mu$
Striae	15 in 10 $\mu$
Punctae	13-15 in 10 $\mu$

*Habitat* — Brackish water Cooum estuary, Madras (!) Adyar estuary, Madras (!)

The form occurs in the littoral region, on the moist soil near the river mouth, Cooum and in Adyar estuary This is found also in the plankton as stray specimens It agrees very well with the type

70 *Amphora coffeeiformis* Agardh

(Figs 104, 105)

Cleve, K. *Sv Vel-Ahad Handl*, part 2, Bd. 27, No. 3, 1895, p. 120, Van Heurck, *Traité des Diatomées*, 1899, p. 134, pl. 24, fig. 681; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 143, fig. 314; Boyer, *Syn N Am Diat*, 1927, p. 260; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 345, fig. 634.

Frustules in girdle view elliptic lanceolate, truncate Valves arcuate on the dorsal margin and straight or slightly concave on the ventral margin Ends of the valves slightly protracted and capitate Striae delicate

*Dimensions —*

Length	35-49 $\mu$
Breadth	11-16 5 $\mu$
Striae	21 in 10 $\mu$

*Habitat* — Brackish water Cooum estuary, Madras (!) Adyar estuary, Madras (!) Ennore backwaters, Madras (!)

The figures given by the various authors differ very much The Madras form agrees best with the figure of W Smith, *Syn Brit Diat*, Vol I, 1853, p 19, Pl XXX, fig 251 (Syn *Amphora salina* W Smith)

The diatom is found in abundance on rocks immersed under water near the mouth of the river Cooum and on moist soil on the banks of the river This is one of the forms which is present throughout the year

71 *Amphora coffeeiformis* Agardh var *africana*

Fritsch and Rich

(Fig 102)

Fritsch and Rich, *Trans Roy Soc. S Africa*, Vol XVIII, part 2, p 112, fig 8 a-d

Valves arcuate on the dorsal margin and straight on the ventral margin The ends are pronouncedly capitate and slightly bent outwards The dorsal side bears slightly divergent punctate striae, the ventral side structureless

*Dimensions —*

Length	25-37 $\mu$
Breadth of the valve	4 5-7 $\mu$
Striae	17-19 in 10 $\mu$

*Habitat* — Brackish water River Cooum, Madras (!)

This form was collected from the upper portion of the river Cooum where the water is fairly brackish

Genus *Cymbella* Agardh, 183072 *Cymbella alpina* Grun

(Fig 124)

Clevr, *Abdr Ver - ikad Handl* part 1 Bd 26, No 2, 1891, p 161, Illustriert, Pl., Pascher's *Süsswasser-Flora* Heft 10, 1930, p. 332, fig 641.

Frustules slightly asymmetrical Valves linear elliptical with convex sides and slightly obtuse ends Raphe straight, slightly eccentric Axial area narrow, slightly dilated in the middle Striae slightly radial and finely transversely lineate

*Dimensions —*

Length	33-38 $\mu$
Breadth	8-10 $\mu$
Striae	6 8 in 10 $\mu$

*Habitat* — Fresh water Hill stream, Kodaikanal, Pulneys, leg., K S Srinivasan

This form was found among other diatoms as a brown scum on decaying fern leaves It agrees very well with the type

73 *Cymbella turgida* (Greg) Cleve

(Fig. 125)

Cleve, *K Sv Vet-Akad Handl.*, part 1, Bd 26, No 2, 1894, p 168; Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 358, fig 600

Valves lunate with highly convex dorsal side and gibbous ventral margin and acute ends Raphe straight, the terminal fissures turned downwards Axial area somewhat broad Striations radial in the middle and slightly convergent at the ends on the ventral side, punctate, puncta coarse

*Dimensions —*

Length	26 3-53 4 $\mu$
Breadth	8 5-12 5 $\mu$
Striae	8-11 in 10 $\mu$

*Habitat* — Fresh water Agric-Hort Gardens ponds, Madras (!) Presidency College garden pond, Madras (!) Masingudi brook, Ootacamund, Nilgiris, leg., T Ekkambaram Vaiyampatti stream, near Trichinopoly, leg., M O P Iyengar Kodaikanal stream, Pulneys, leg., K S Srinivasan

Hustedt gives the range of the length of the diatom as 30-100  $\mu$  but states that most of the individuals are on the smaller side The South Indian forms range from 26 3-53 4  $\mu$  The minimum length recorded for the South Indian form, viz., 26 3, is slightly lower than the minimum recorded previously for the type

74 *Cymbella Hustedtii* Krasske

(Fig. 123)

Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p. 363, fig 674.

Valves asymmetrical, elliptic lanceolate with convex sides and rounded ends Raphe less eccentric Axial area narrow, not widened in the middle Striations somewhat coarse and slightly radial.

*Dimensions —*

Length	.	18.6-20 $\mu$
Breadth	.	7 $\mu$
Striae		12-13 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, near Trichinopoly, leg., M O P Iyengar Red Hills Lake, Madras, leg., S V Ganapati

This form agrees with the dimensions and figure given by Hustedt.

75 *Cymbella cistula* (Hemp) Grun var  
*maculata* (Kutz) Van Heurck  
(Fig 136)

Van Heurck, *Traité des Diatomées*, 1899, p 117, pl 1, fig 11. Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 363, fig 676 b

Frustules asymmetrical, boat-shaped Valves with ventral gibbous margin and truncate rounded ends Terminal fissures reflexed Striations radial, punctate No isolated puncta on the ventral side

*Dimensions —*

Length	74-140 $\mu$
Breadth	18-31 $\mu$
Striae	7-9 in 10 $\mu$
Punctæ	18-22 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, near Trichinopoly, leg., M O P Iyengar

This form agrees with the type quite well

76 *Cymbella naviculiformis* Auerswald  
(Fig 119)

Cleve, *K. Sv. Vet Akad Handl*, part 1, Bd 20, No 2, 1894, p 166, Boyer, *Syn. N. Am. Diat*, 1927, p 281, Hustedt, Fr., Pascher's *Süsswasser-Flora*, Heft 10, 1930, p 356, fig 653

Valves elliptic lanceolate with rostrate capitate ends Raphe less eccentric Axial area narrow, linear, suddenly dilated in the middle Striations radial, closer towards the ends, puncta very fine

*Dimensions —*

Length	30 $\mu$
Breadth	10 $\mu$
Striae in the middle	12-14 in 10 $\mu$
Striae at the ends	18 in 10 $\mu$

*Habitat* — Fresh water stream, Bearshola, Kodai Kanal, Pulneys, leg., K S Srinivasan

This form agrees with the type quite well

Genus *Gomphonema* Agardh, 1824

77 *Gomphonema sphaerophorum* Ehr forma *subcapitata* f nov

(Figs 126, 127, 128)

Valves elliptic, club-shaped with capitate round apex and base. The capitate base is either smaller, equal or bigger than the capitate apex. The constriction at the apex is only slight. Axial area narrow, linear, central area small, unilateral with one stigma. Striations slightly radial.

*Dimensions* —

Length	25-38 $\mu$
Breadth	6-8 5 $\mu$
Striae	13-15 in 10 $\mu$

*Habitat* — Fresh water Presidency College pond, Madras, leg., Miss John. Fresh water stream, Masingudi, Ootacamund, Nilgiris, leg., T Ekambaram.

The form agrees in most respects with the type but differs from it in the nature of its apical portion which is not so capitate as in the type. The constriction below the capitate portion is not so very pronounced as in Hustedt's figure (Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 372, fig 695). Again in shape the diatom varies from thin and long to short and stout. In all other respects it agrees with the type.

78 *Gomphonema parvulum* (Kutz) Grun

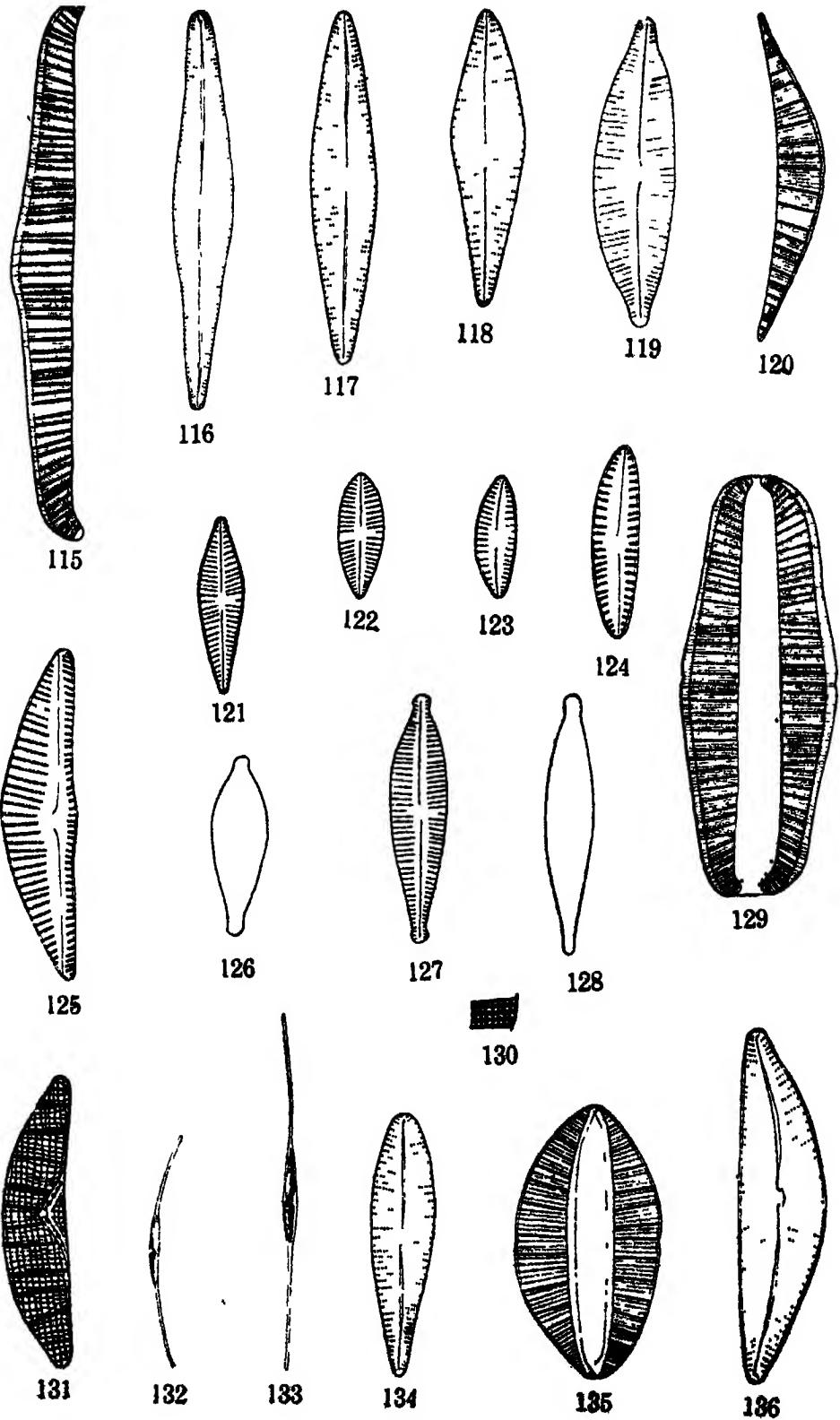
(Fig 121)

Cleve, *K Sv Vet.-Akad Handl*, part 1, Bd 28, No 2, 1894, p 180; Van Heurck, *Traité des Diatomées*, 1899, p 272, pl 7, fig 306; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 124, fig 270; Boyer, *Syn N Am Diat*, 1927, p 294, Petersen, J. B., *Botany of Iceland*, Vol II, part 2, 1928, p 411, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 372, fig 713 a.

Valves lanceolate, club-shaped gradually tapering from the middle to the ends. Apex rostrate. Axial area very narrow, central area unilateral with an isolated stigma. Striations radial, very finely punctate.

*Dimensions* —

Length	24-32 $\mu$
Breadth	5-7 $\mu$
Striae	.. . 14-16 in 10 $\mu$



*Habitat*—Fresh water Vaiyampatti stream near Trichinopoly, leg.  
M O P Iyengar

This form agrees with the type quite well

79 *Gomphonema parvulum* (Kütz.) Grun  
var *subelliptica* Cleve  
(Fig 122)

Cleve, *K. Sv Vet-Akad Handl*, part 1, Bd. 26, No 2, 1894 p. 180; Hustedt, Fr.,  
Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 373, fig 713 b

Frustules more symmetrically elliptic lanceolate with scarcely rostrate apex Smaller than the species

*Dimensions*—

Length	14 $\mu$
Breadth	5 $\mu$
Striae	14 in 10 $\mu$

*Habitat*—Fresh water Vaiyampatti stream near Trichinopoly, leg.  
M O P Iyengar

It was a very rare form in the collection The specimens agree with the type

80 *Gomphonema intricatum* (Kütz) var  
*vibrio* (Ehr) Cleve  
(Fig 116)

Cleve, *K. Sv Vet-Akad Handl*, part 1, Bd 26, No. 2, 1894, p 182, Schönenfeldt,  
Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 122, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 376, fig 698

- 
- Fig. 115.—*Rhopalodia gibba* (Ehr) O Müll.  $\times 1000$   
Fig. 116.—*Gomphonema intricatum* (Kütz) var *vibrio* (Ehr) Cleve  $\times 700$ .  
Fig. 117.—*Gomphonema lanceolatum* Ehr  $\times 1100$   
Fig. 118.—*Gomphonema lanceolatum* Ehr var *insignis* (Greg) Cleve  $\times 1100$   
Fig. 119.—*Cymbella naviculariformis* Auerwald  $\times 1600$   
Fig. 120.—*Rhopalodia gibberula* (Ehr.) O Müll. var *protracta* Grun.  $\times 1100$   
Fig. 121.—*Gomphonema parvulum* (Kütz) Grun.  $\times 1500$   
Fig. 122.—*Gomphonema parvulum* (Kütz) Grun. var *subelliptica* Cleve  $\times 1500$   
Fig. 123.—*Cymbella Hustedti* Krasske  $\times 1100$ .  
Fig. 124.—*Cymbella alpina* Grun.  $\times 1100$   
Fig. 125.—*Cymbella turgida* (Greg) Cleve  $\times 1100$   
Figs. 126-28.—*Gomphonema sphaerophorum* Ehr f *subcapitata* f. nov.  $\times 1000$   
Fig. 129.—*Rhopalodia gibba* (Ehr.) O Müll. var *ventricosa* (Ehr) Grun.  $\times 1000$   
Fig. 130.—*Rhopalodia gibberula* (Ehr.) O Müll. Showing rows of serioles between two ribs  $\times 1600$   
Fig. 131.—*Epithemma sebra* (Ehr) Kütz. var *saxonica* (Kütz.) Grun.  $\times 1100$   
Figs. 132-33.—*Nitzschia closterium* (Ehr) W. Smith Showing chloroplasts  $\times 700$   
Fig. 134.—*Gomphonema lanceolatum* Ehr  $\times 1100$   
Fig. 135.—*Rhopaledia gibberula* (Ehr.) O Müll.  $\times 1100$ .  
Fig. 136.—*Cymbella cistula* (Hemp.) Grun. var *maculata* (Kütz.) Van Heurck  $\times 1100$ .

Valves very slender, narrow and linear, slightly gibbous in the middle with rounded truncate ends Axial area fairly broad Central area broad, unilateral with an isolated stigma Striations slightly radial, clearly punctate

*Dimensions —*

Length	.. 100 $\mu$
Breadth	10 $\mu$
Striae	10 in 10 $\mu$

*Habitat* — Fresh water Pond inside Agri-Hort Gardens, Madras (!)

This form was found as a rare one in the collection It agrees very well with the description given by Cleve and Hustedt and with the figure given by Hustedt

81 *Gomphonema lanceolatum* Ehr

(Figs 117, 134)

Cleve, K. Sv. Vet.-Akad. Handl., part 1, Bd 26, No 2, 1894, p 183; Schönfeldt, Pascher's Süsswasser-Flora, Heft 10, 1913, p 123, fig. 268. Boyer, Syn. N. Am. Diat., 1927, p 295. Hustedt, Fr. Pascher's Süsswasser-Flora, Heft 10, 1930, p 376, fig 700

Valves club-shaped to lanceolate club-shaped with obtuse apex and somewhat tapering basis Axial area broad Central area small, unilateral with an isolated stigma Striations coarse, slightly radial, punctate, puncta big

*Dimensions —*

Length	40-54 $\mu$
Breadth	9-10 $\mu$
Striae	12-13 in 10 $\mu$

*Habitat* — Fresh water Ponds in the Agri-Hort Gardens, Madras (!)

This form agrees with the type

82 *Gomphonema lanceolatum* Ehr var

*insignis* (Greg) Cleve

(Fig 118)

Cleve, K. Sv. Vet.-Akad. Handl., part 1, Bd 26, No. 2, 1894, p. 183; Boyer, Syn. N. Am. Diat., 1927, p 295, Hustedt, Fr. Pascher's Süsswasser-Flora, Heft 10, 1930, p 376, fig 700

This is distinguished from the species through the slightly distant striae, 8-10 in 10  $\mu$  The apex is slightly more tapering than the type

*Habitat* — Fresh water Ponds in the Agri-Hort Gardens, Madras (!)

This form agrees very well with the description and figure given by Hustedt.

## (2) Family EPITHEMIACEAE

## (a) Subfamily Epithemioideæ

Genus *Epithemia* Brebisson, 183883 *Epithemia zebra* (Ehr.) Kütz var *saxonica* (Kütz) Grun

(Fig 131)

Schönenfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 148. Hustedt, Fr.,  
Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 385, fig 730

Valves arcuate with rounded and slightly produced ends Dorsal side rather highly convex and the ventral side slightly concave Costæ robust, alternating with more than two rows of aerioleæ

*Dimensions* —

Length	44-46 $\mu$
Breadth	9.5-10 $\mu$
Costæ	2-4 in 10 $\mu$
Rows of aerioles	. 12 in 10 $\mu$

*Habitat* — Fresh water On decaying fern leaves in a stream in Bearshola, Kodaikanal, Pulneys, leg, K S Srinivasan

It was a very rare form in the collection This specimen agrees with the type

## (b) Subfamily Rhopalodioideæ

Genus *Rhopalodia* O Müller, 189584 *Rhopalodia gibba* (Ehr.) O Mull

(Fig 115)

O Müller, Engler's *Botan Jahrbücher*, Bd 22, 1895, p 65. Taf 1, figs 15-17. Schönenfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 147, fig 324. Boyer, *Syn N Am Diat.*, 1927, p 491. Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 390, figs 740, 740a

Frustules in girdle view linear, gibbous in the middle, broad, gradually slightly tapering to the ends Valves linear, arcuate on the dorsal, straight on the ventral side, reflexed at the ends Costæ strong, two to three aeriole rows between two costæ.

*Dimensions* —

Length	83-104 $\mu$
Breadth	21-25 $\mu$
Costæ	. . . 6-8 in 10 $\mu$

*Habitat* — Fresh water brook, Masingudi, Ootacamund, Nilgiris, leg. T Ekambaram Red Hills Lake, Madras, leg., S V Ganapati

The rows of aerioles were not observed even under a very high magnification. The specimens agree with the type.

85 *Rhopalodia gibba* (Ehr.) O Müll  
var *ventricosa* (Ehr.) Grun  
(Fig 129)

Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 391, fig. 741

This variety is distinguished from the species by its strongly gibbous nature in the middle, tapering strongly towards the ends, thus making the frustule compact.

*Dimensions* —

Length	66 $\mu$
Breadth	21 $\mu$
Costæ	6-8 in 10 $\mu$

*Habitat* — Fresh water brook, Masingudi, Ootacamund, Nilgiris, leg. T Ekambaram

This form was found only as a stray specimen among the species Hustedt (*op cit*, p 391) has observed such an occurrence. The few specimens that were noticed are similar to the figure given here. The tapering from the middle to the ends is intermediate between the species *gibba* (Ehr.) O Müll and the var *ventricosa* (Ehr.) O Müll.

86 *Rhopalodia gibberula* (Ehr.) O Müll  
(Figs 130, 135)

Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p. 148, fig 326; Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 391, fig 742

Frustules in girdle view long, elliptical with rounded ends. Dorsal side highly convex, ventral side more or less straight in the middle portion. The aerole rows distinctly seen between two costæ.

*Dimensions* —

Length	35-42 $\mu$
Breadth	20-24 $\mu$
Costæ	3-4 in 10 $\mu$
Rows of aerioles between two costæ	2-8

*Habitat* — Brackish water Adyar estuary, Madras (!)

This form agrees with the figure and description given by Hustedt.

87 *Rhopalodia gibberula* (Ehr.) O Müll  
 var *protracta* Grun  
 (Fig 120)

Hustedt, Fr., Pascher's *Süßwasser Flora*, Heft 10 1930, p 391, fig 748

This slightly differs from the species in having a slight depression on the dorsal margin near the ends Ends taper and are pointed

*Dimensions* —

Length	53-4 $\mu$
Costæ	3-4 in 10 $\mu$
Rows of aeroles between two costæ	2-8

*Habitat* — Brackish water Adyar estuary, Madras (!)

This form was found along with other brackish water diatoms on mud inside water as a greenish film It agrees with the type

(3) Family NITZSCHIACEÆ

Subfamily Nitzschioideæ

Genus *Hantzschia* Grun 1880

88 *Hantzschia amphioxys* (Ehr.) Grun var *vivax* (Hantz.) Grun  
 (Fig 148)

Van Heurck, *Traité des Diatomées* 1899, p 381 pl 15, fig 486 b, Schönenfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 161, Boyer, *Syn N Am Diat*, 1927, p. 528, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 394, fig 750

Valves linear, slender and with longer ends than the species Keel puncta short, the median distant

*Dimensions* —

Length	61-75 $\mu$
Breadth	6-5-8 $\mu$
Keel puncta	6-8 in 10 $\mu$
Striae	13-18 in 10 $\mu$

*Habitat* — Fresh water Pools near Elliot Beach, Madras, leg, M O P Iyengar An irrigation tank at Vandalur, Madras, leg, K G Veeraraghavan

This is a rare form in the collections Only a few stray specimens were found This form agrees with var *vivax* in all respects

Genus *Bacillaria* Gmelin, 1788

89 *Bacillaria paradoxa* Gmelin  
 (Figs 144, 145)

De Toni, *Syll Alg.*, Vol II, part 1, 1891, p 498, Schönenfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 149, fig 328, Karsten, G., Engler and Prantl's *Nat. Pflanzenfamilien*, Bd. 2, 1928, p. 294, figs 399, 100, 190 Lebour, M V., *Planktonic*

*Diatome of Northern Seas*, 1930 p 211, fig 175, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930 p 396, fig 755 a b

Frustules in girdle view linear rectangular united in bundles to form plates Valves linear, spindle-shaped Carnal dots form a row in the middle portion of the valve The striae are very fine

*Dimensions* —

Length	80-105 $\mu$
Breadth	5-6 $\mu$
Carnal dots	6-8 in 10 $\mu$
Striae	20-25 in 10 $\mu$

*Habitat* — Brackish water Adyar estuary, Madras (!)

This form occurred among other diatoms on the surface of the moist soil as a brownish scum They were showing the characteristic gliding movements when collected

*Genus Nitzschia Hassal, 1845*

*Section Tryblionella* (W Smith, Grunow) Hustedt

90 *Nitzschia tryblionella* Hantzsch var *levidensis* (W Smith) Grun  
(Fig 141)

Van Heurck, *Traité des Diatomées*, 1899, p 385, pl 15, fig. 404; Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 151, Boyer, *Syn N Am. Diat.*, 1927, p 495, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 399, fig 780

Valves linear with slightly concave margins Ends wedge-shaped and rounded A clear longitudinal fold in the middle of the valve is present Keel very eccentric Striae clear

*Dimensions* —

Length	40 $\mu$
Breadth	9 $\mu$
Keel puncta	12 in 10 $\mu$
Striae	11-13 in 10 $\mu$

*Habitat* — Fresh water stream, Vaiyampatti, near Trichinopoly, leg. M O P Iyengar Fresh water pond, Presidency College Garden, Madras (!)

This is a rare form in both the collections. The ends are a bit more produced than in the var *levidensis* as figured by Hustedt

*Section Lineares* (Grun) Hust

91 *Nitzschia vitrea* Norman

(Fig 143)

Van Heurck, *Traité des Diatomées*, 1899, p 399, pl. 16, fig. 544; Boyer, *Syn. N Am. Diat.*, 1927, p 519. Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 411, fig 787.

Frustules in girdle view linear, rectangular, with parallel sides and truncate rounded ends Valves narrow, with parallel margins Keel puncta somewhat rounded Striations fine but distinct

*Dimensions --*

Length	76-101 $\mu$
Breadth ..	7 6-11 $\mu$
Keel puncta	5-7 in 10 $\mu$
Striae	20-22 in 10 $\mu$

*Habitat* — Brackish water Plankton of river Cooum, Madras (!)

This was only a stray form in the plankton It agrees with the type quite well

*Section Lanceolatae Grun*

92 *Nitzschia amphibia* Grun

(Fig 149)

Van Heurck, *Traité des Diatomées*, 1899 p 103 pl 17 fig 503, Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 158, fig 349, Boyer, *Syn N Am Dial.*, 1927, p 521, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 414, fig 703

Valves linear to linear lanceolate with the ends slightly produced sometimes and rounded Striations coarse and punctate, puncta big

*Dimensions --*

Length	14-30 $\mu$
Breadth	4-5 $\mu$
Keel puncta	6-8 in 10 $\mu$
Striae	14-17 in 10 $\mu$

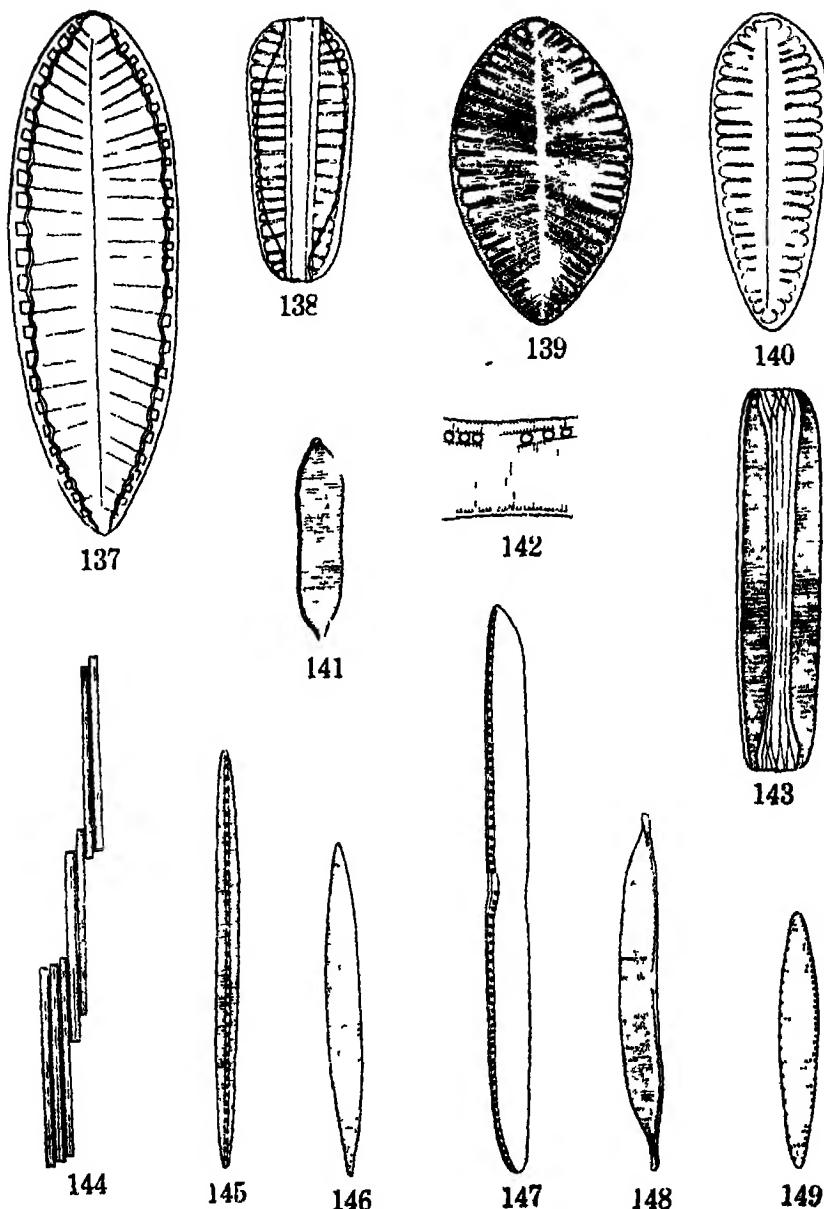
*Habitat* — Fresh water Common and widely distributed Ponds, Agricultural Garden, Madras (!) Adyar fresh water pond, Madras (!) Roadside ditch, Guindy, Madras (!) Stream, Vaiyampatti, near Trichinopoly, leg. M O P Iyengar On the moist wall of a house, Triplicane, Madras, leg. M O P Iyengar, wherein only this species was found as a pure species in abundance

This form agrees very well with the type

93 *Nitzschia palea* (Kütz) W Smith

(Fig 146)

Smith, W., *Syn. Brit. Dial.*, Vol II, 1853, p 89, Van Heurck, *Traité des Diatomées*, 1899, p 401, pl 17, fig 554, Schönfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 159, fig. 352; Boyer, *Syn N Am. Dial.*, 1927, p 521, Hustedt, Fr., Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 416, fig. 801

FIG. 137.—*Surrella tenera* Greg.  $\times 700$ FIG. 138.—*Surrella elegans* Ehr. (Hindle view)  $\times 300$ .FIG. 139.—*Surrella ovalis* Breb.  $\times 1000$ FIG. 140.—*Surrella elegans* Ehr. Valve view  $\times 350$ FIG. 141.—*Nitzschia tryblionella* Hantz. var. *lucidula* (W. Smith) Grun.  $\times 800$ .

Valves linear to linear lanceolate with short wedge-shaped tapering ends  
 Striations very delicate

*Dimensions* —

Length . . . . .	40-54 $\mu$
Breadth . . . . .	3-4 5 $\mu$
Keel punctæ . . . . .	10-15 in 10 $\mu$
Striae . . . . .	about 40 in 10 $\mu$

*Habitat* — Fresh and brackish water This is a common form found in pools, ponds, streams, ditches, moist soil, etc. This forms the plankton of the river Cooum, during the North-East Monsoon season It occurs in abundance on the moist soil of the beach during this season

It agrees well with the type

Section *Obtusa* (Grun) Hust

94 *Nitzschia obtusa* W Smith var

*scalpelliformis* Grun

(figs 142, 147)

Van Heurck, *Traité des Diatomées*, 1899, p 307, pl 16, fig 538, Boyer, *Syn N Am Diat*, 1927, p 517; Hustedt, Fr, Pascher's *Süsswasser-Flora*, Heft 10, 1930 p 422, fig 817 d

Frustules broad, linear with ends obliquely truncate Keel fairly large, inflexed in the middle region The two median keel puncta distant Striations punctate punctæ fine and linear

*Dimensions* —

Length . . . . .	89-112 $\mu$
Breadth . . . . .	10-12 $\mu$
Keel punctæ . . . . .	6-8 in 10 $\mu$
Striae . . . . .	26-27 in 10 $\mu$

*Habitat* — Brackish water River mouth, Cooum, Madras (!) Adyar estuary, Madras (!)

Fig. 142.—*Nitzschia obtusa* W Smith var. *scalpelliformis* Grun Showing the carnal dots and the transverse punctate striae  $\times 1600$ .

Fig. 143. *Nitzschia vitrea* Norman. Girdle view  $\times 800$

Fig. 144.—*Bacillaria paradoxa* Gmelin Cells in a band.  $\times 350$ .

Fig. 145.—*Bacillaria paradoxa* Gmelin Valve view  $\times 700$

Fig. 146.—*Nitzschia palea* (Kütz.) W. Smith.  $\times 1100$ .

Fig. 147.—*Nitzschia obtusa* W Smith var *scalpelliformis* Grun  $\times 700$ .

Fig. 148.—*Hantzschia amphioxys* (Ehr.) Grun var *vivar* (Hantzsch) Grun  $\times 800$ .

Fig. 149.—*Nitzschia amphibia* Grun  $\times 1500$

This form is found in the littoral region and also in the plankton of the river Cooum. It agrees with the type. The striations when seen under very high magnification are composed of fine linear punctæ.

Section *Nitzschia* (Rabh.) Grun  
 96 *Nitzschia closterium* (Ehr.) W Smith  
 (Figs 132, 133)

Smith, W., *Syn. Brit. Diat.*, Vol I, 1853, p 42, pl XV, fig 120. Gran, H II, *Nordisches Plankton, Botanischer Teil*, B VIII, 10, 1908, p 129 fig 172; Boyer, *Syn N Am Diat.*, 1927, p 526, Lebour M V, *The Planktonic Diatoms of Northern Seas* 1930, p 212, fig 176, Hustedt, Fr. Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 421, fig 822.

Valves spindle-shaped in the middle. The ends extended into long beaks usually slightly bent in a semi-circle or sometimes curved in opposite directions. Striations not recognizable.

*Dimensions* —

Length	70-116 5 $\mu$
Breadth	3 5-6 $\mu$

*Habitat* — Brackish water. Plankton of the river Cooum, Madras. This was almost constantly present in the plankton throughout the year. The maximum development was during the month of January when they were found as 52,000 per c.c. of the water, colouring the water yellowish brown. Kolbe (*Planzenforschung*, Heft 7, 1927, p 103) remarks about the occurrence of this in abundance during spring.

This form agrees with the type.

(4) Family SURIRELLACEÆ  
 (a) Subfamily Surirelloideæ  
 Genus *Surirella* Turpin, 1828  
 96 *Surirella tenera* Gregory  
 (Fig 137)

Gregory, *Quart Jour Mus Sci.*, Vol IV, 1856 p 11, Boyer, *Syn N Am. Diat.*, 1927, p 540. Hustedt, Fr. Pascher's *Süßwasser-Flora*, Heft 10, 1930, p. 438, fig. 853.

Valves narrowly elliptical, rounded at one end and acute at the other. Central space narrow. Costæ rather indistinct and faint.

*Dimensions* —

Length	110-140 $\mu$
Breadth	. . 31-37 $\mu$
Costæ	. . 25-40 in 100 $\mu$

*Habitat*—Fresh water stream, Bearshola, Kodaikanal, Pulneys, leg., K. S Srinivasan

This form agrees with the description and figures given by Gregory and Hustedt.

97 *Surirella elegans* Ehr

(Figs 138, 140)

Schönsfeldt, Pascher's *Süßwasser Flora*, Heft 10, 1913, p 167, fig 372, Bover, *Syn N Am Diat*, 1927, p 537, Hustedt, Fr Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 440, figs 858, 859

Frustules in girdle view wedge-shaped Valves narrowly or broadly ovate, rounded at one end and acute at the other end Central space narrow, lanceolate Costæ broad

*Dimensions*—

Length	146-200 $\mu$
Breadth	52-70 $\mu$
Costæ	14-16 in 100 $\mu$

*Habitat*—Fresh and slightly brackish water Common Fresh water ponds, Agri-Hort Gardens, Madras (!) Stream, Vaiyampatti, near Trichinopoly, leg., M O P Iyengar An irrigation tank at Vandalur, Madras, leg., K G Veceraghavan River Cooum, from the upper portion (!)

This fresh water form was also able to grow in portions of the river where the salinity of the water ranged upto 0.075% Kolbe groups this under "indifernt forms"

98 *Surirella ovalis* Brebisson

(Fig 139)

Smith, W, *Syn Brit. Diat*, Vol I, 1853, p 33, pl IX, fig 68, Schönsfeldt, Pascher's *Süßwasser-Flora*, Heft 10, 1913, p 170, fig 374, Bover, *Syn N Am Diat*, 1927, p 541, Hustedt, Fr Pascher's *Süßwasser-Flora*, Heft 10, 1930, p 441, figs 860, 861

Valves ovate, acuminate, costæ short, marginal, radial and unequal Central space rather indistinct Striations radial

*Dimensions*—

Length	.	..	..	42-80 $\mu$
Breadth	.	..	..	28-43 $\mu$
Costæ	..	..	..	44-48 in 10 $\mu$
Striae	.	..	..	15 in 10 $\mu$

*Habitat*—Fresh water Brook, Masingudi, Nilgiris, leg., T. Ekambaram

This form agrees with the type. The inner limit of the costae are clearer under a higher focus.

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## EXPLANATION OF MICROPHOTOGRAPHS

## PLATE XVII

- FIG. 1 — *Achnanthes coarctata* Breb var *parallella* var nov Showing their epiphytic nature Cells are united both by their valves and by their ends  $\times 180$
- FIG. 2 — *Coccinodiscus Granii* Gough Valve showing the areolations  $\times 130$
- FIG. 3 — *Diploneis subovalis* Cleve Showing the double rows of alveoli  $\times 2000$
- FIG. 4 — *Diploneis subovalis* Cleve The same frustule (as in fig 3) taken at a lower focus Showing the prominent costae with their capitate ends almost touching one another  $\times 2000$

## Statement showing the Distribution of the Forms Recorded in this Paper in the Indian Region

	Places of collection in S India	Previous places of collection in India	Author
<i>Achanthes Hauckiana</i> Grun	Br Water, Madras	..	
<i>Achanthes inflata</i> (Kütz.) Grun	Fr.† Water Madras, Ootacamund	..	
<i>Achanthes corrifolia</i> (Breb.) Grun var <i>parvella</i> var nov	Br Water, Madras	..	
<i>Achanthes brevipes</i> Agardh var <i>intermedia</i> (Kütz.) Cleve	Fr Water and Br Water, Madras	Peradeniya, Ceylon	Skvortzow (1930)
<i>Amphora paludosa</i> W. Smith var <i>subsinuata</i> Cleve	Br Water, Madras	..	.
<i>Amphora holotheca</i> Hust	Br Water, Madras	..	
<i>Amphora coffeeiformis</i> Agardh	Br Water, Madras	Calcutta, Khewra	Skvortzow (1935) Abdul Majeed (1935)
<i>Amphora coffeeiformis</i> Ag. var <i>africana</i> Fritsch and Rich	Madras	..	
<i>Anomozensis sphaerophora</i> (Kütz.) Pfitzer	Fr Water, Madras, Kodai-Kanal	All over Panjab	Abdul Majeed (1935)
<i>Anomozensis sphaerophora</i> (Kütz.) Pfitzer var <i>scrupula</i> (Ehr.) O. Müll f. <i>indica</i> f. nov	Fr. Water, Madras	..	
<i>Asterosella japonica</i> Cleve	..	Marine, found near the mouth of the river Cooum, Madras	R. Gopala Iyer and Senkara Menon (1930)
<i>Bacillaria paradoxa</i> Gmelin	Br Water Madras	Madras coastal diatoms	Do
<i>Caloneis Schenkemsonia</i> (Grun.) Cleve var. <i>biconstricta</i> Grun.	Fr Water, Madras	..	
<i>Chadoceras orientalis</i> Schiller	..	Br Water, Madras	..

<i>Ceriodinodus</i> Gough	..	Marine, found in the river mouth, Cooum, Madras	
<i>Cyckotella stelligera</i> Cl. und Grun.	.	Fr. Water, Vandalur lake, Madras	
<i>Cyclotella meneghiniana</i> Kütz.	.	Fr. and Br. water, common, Madras, Ottacanund	Abdul Majeed (1935)
<i>Cyclotella kuetzingiana</i> Thwaites	.	Br. Water	Salt range, Khewra Gorge Chalisa, Punjab
<i>Cymbella alpina</i> Grun.	.	Fr. Water, Kodarkanal Hills	
<i>Cymbella turgida</i> (Greg.) Cleve	.	Fr. Water, common, Madras	A. Grunov (1865)
<i>Cymbella hastellata</i> Kraske	.	Fr. Water, Madras	
<i>Cymbella cristula</i> (Hemp.) Grun var. <i>maculata</i> (Kütz.) Van Heurck	.	Fr. Water, Vavayampatti	
<i>Cymbella nemoralis</i> Ausenwald	.	Fr. Water, Kodarkanal Hills	
<i>Cocconeis placenta</i> Ehr var. <i>euglypta</i> (Ehr) Cleve	.	Fr. and slightly Br. water, Madras, Vayampatti, Coonoor	Peradeniya, Ceylon Skvortzow (1930)
<i>Diploneis subcordalis</i> Cleve	.	Fr. Water Pytara, Coonoor	
<i>Diploneis intercipita</i> (Kütz.) Cleve	.	Br. Water, Madras	
<i>Fusaria pectinata</i> (Hilew. & Kütz.) Rabh	.	Fr. Water, Madras	
var. <i>grahamiae</i> var. nov.	.		
<i>Fusaria monodon</i> Ehr	.	Fr. Water, Madras	Batong valley, Sikkim, Himalayas, Peradeniya, Ceylon
<i>Fusaria pseudokutneri</i> sp. nov.	..	Fr. Water, Travancore	Dickie George (1882) Skvortzow (1930)
<i>Epeorus rotens</i> (Ehr.) Kütz. var. <i>exostora</i> (Kütz.) Grun.	.	Fr. Water, Kodakana	..
<i>Fragilaria intermedia</i> Grun var. <i>robusta</i> var. nov.	.	Fr. Water, Madras	..

\* Fr. Water = Fresh Water      † Fr. Water = Brackish Water

## Statement showing the Distribution of the Forms Recorded in this Paper in the Indian Region—(Contd.)

	Places of collection in S India	Previous places of collection in India	Author
<i>Praylaria heterosticha</i> Grun f. <i>elongata</i> f. nov	Fr Water, Madras	.	.
<i>Gomphonema sphaerophorum</i> Ehr f. <i>subcapitata</i> f. nov	Fr Water, Madras	.	Schearschmidt (1886)
<i>Gomphonema parvulum</i> (Kütz.) Grun	Fr Water, Madras	Afghanistan, Banks Island, Calcutta	Grunow (1887), Skvor- tzow
<i>Gomphonema porcellum</i> (Kütz.) Grun var <i>subelliptica</i> Cleve	Fr Water, Madras	Kottava, Ceylon	Skvorzow (1930)
<i>Gomphonema intricatum</i> Kütz var <i>vibrio</i> (Ehr.) Cleve	Fr Water, Madras	Banks Island, Assam valley, Peradeniya, Ceylon	A. Grunow (1885) Carter, N. (1926) Skvorzow (1930)
<i>Gomphonema lanceolatum</i> Ehr	Fr Water, Madras	Ceylon	Fortmirel
<i>Gomphonema distortum</i> (W. Smith) Cleve var. Parker Harrison	Br Water, Madras	.	Skvorzow (1930)
<i>Gyrosigma balicum</i> (Ehr.) Rabh	Slightly Br. Water, Madras	.	.
<i>Gyrosigma distortum</i> (W. Smith) Cleve var. Parker Harrison	Br Water, Madras	.	.
<i>Gyrosigma socioprae</i> (Rabh.) Cleve var. <i>eximia</i> (Thwaites) Cleve	Br Water, Madras	.	.
<i>Hednottia amphioxys</i> (Ehr.) Grun var <i>varia</i> (Hartzaeh) Grun	Fr Water, Madras	.	.
<i>Mastigiosia dolosa</i> sp. nov	Br Water, Madras	.	.
<i>Mastigiosia Brauni</i> Grun	..	.	.
<i>Mastigiosia exigua</i> Lewis f. nov	Br Water, Madras	.	.

<i>Melosira dubia</i> Kütz	..	Br Water, Ennore, Madras	W. West and G. S. West (1907); W. West and G. S. West (1901-5)
<i>Melosira granulata</i> (Ehr.) Ralfs.	..	Fr Water, Madras	Pegn, Burns Peradeniya, Ceylon
<i>Melosira granulata</i> (Ehr.) Ralfs var <i>angustissima</i> Müll	Fr Water, Madras	Fr Water, Madras, Masungudi, Nilgiris	Peradeniya, Ceylon, Calcutta
<i>Nancula cuspidata</i> Kütz var <i>conspicua</i> var nov.	Fr Water, Vayampatti, Madras	Fr Water, Vayampatti, Nilgiris	Skyvortzow (1930)
<i>Nancula cuspidata</i> Kütz var <i>ambigua</i>	Br Water, Madras	Br Water, Madras	Skyvortzow (1935)
<i>Nancula holophila</i> (Grun.) Cleve f <i>sub-explicata</i> Ostrup	Br Water, Madras	Br Water, Madras	..
<i>Nancula protrada</i> Grun	..	Br Water, Madras	..
<i>Nancula Saltinum</i> Grun	..	Br Water, Madras	..
<i>Nancula rostellata</i> Kütz	..	Br Water, Madras	..
<i>Nancula cincta</i> (Ehr.) Kütz var <i>Heufieri</i> Grun.	..	..	..
<i>Nancula gracilis</i> Ehr	..	..	..
<i>Nancula peregrina</i> (Ehr.) Kütz var <i>Kefren-gensis</i> (Ehr.) Cleve	..	..	..
<i>Nancula digitoradiata</i> (Greg.) A. Schmidt	..	..	..
<i>Nancula laterostriata</i> Hust	..	..	..
<i>Nancula hastata</i> Pant	..	..	..
<i>Nancula lacustris</i> Greg var <i>major</i> var nov	..	..	..
<i>Nancula lyra</i> Ehr	..	..	..
<i>Nancula payntera</i> Kütz	..	..	..

## Statement showing the Distribution of the Forms Recorded in this Paper in the Indian Region—(Contd.)

	Places of collection in S. India	Previous places of collection in India	Author
<i>Nitschia tricholeuca</i> Hantz. var. <i>lendens</i> (W. Smith) Grun.	Fr. Water, Madras	..	
<i>Nitschia rufra</i> Norman	Br. Water, Madras	Sipna Valley, Calcutta	Carter, N (1926) Skvortzow (1935)
<i>Nitschia amphibia</i> Grun	Fr. Water, Madras	Vizagapatam Calcutta, Ceylon	W. West and G. S. West (1907) Skvortzow (1935)
<i>Nitschia palea</i> (Kütz.) W. Smith	Fr. and Br. Water	Calcutta	W. West and G. S. West (1901-5) Skvortzow (1935)
<i>Nitschia obtusa</i> W. Smith var. <i>sculpta</i> — former Grun.	Br. Water, Madras		
<i>Nitschia cladotricha</i> W. Smith	..	Br. Water, Madras	
<i>Pseuderaria fasciata</i> (Legrandet) Hust		Fr. Water, Vayampatti, Madras	
<i>Pinnularia interrupa</i> W. Smith f. <i>genseana</i> Fritsch	Fr. Water, Madras		
<i>Pinnularia interrupa</i> f. <i>subcapitata</i> Fritsch	Fr. Water, Madras		
<i>Pseuderaria Brossia</i> (Grun.) Cleve var. <i>graphicephala</i> (A. Meyer) Hust. f. <i>subconica</i> f. nov.		Fr. Water, Madras	
<i>Pseuderaria kereas</i> Ehr		Calcutta	
<i>Pseuderaria gibba</i> Ehr f. <i>subundulata</i> Mayer	Fr. Water, Madras		Ehrenberg
<i>Pseuderaria gibba</i> Ehr f. <i>undulata</i> f. nov.	Fr. Water, Madras		

<i>Pinnularia acutipennis</i> Brébisson .	Fr Water, Madras, Technopoly	Peradeniya, Ceylon	Skvortzow (1930)
<i>Pinnularia striata</i> (Nitzsch) Ehr ..	Fr Water, Madras	Burma	W West and G S West (1907)
<i>Plaetzingia angulatum</i> (Quekett) W Smith	Br Water, Madras	.	.
<i>Plaetzingia solitarium</i> Grun	Br Water, Madras	.	.
<i>Rhopalodia gibba</i> (Ehr.) O Mill	Fr Water, Nilgiris, Madras	Loktak Lake, Manipur	K Biswas (1936)
<i>Rhopalodia gibba</i> (Ehr.) O Mill. var <i>ventri-</i> <i>cosa</i> (Ehr.) Grun.	Fr Water, Nilgiris	.	.
<i>Rhopalodes gibberula</i> (Ehr.) O Müll.	Br Water, Madras	.	Abdul Majeed (1935)
<i>Rhopalodes gibberula</i> (Ehr.) O Müll. var <i>pro-</i> <i>tracta</i> Grun.	Br Water, Madras	.	.
<i>Scletonema costatum</i> (Grev.) Cleve	Br Water, Madras	Madras coast	.
<i>Sleuronema acicula</i> (Grev.) Cleve	Fr Water, Madras, Nilgiris	.	R Gopala Iyer and Sankara Menon (1936)
<i>Synechra ulna</i> (Nitzsch) Ehr	Fr Water, Madras, Nilgiris	Burma, Ceylon, Manipur, Assam	W West and G S West (1907)
<i>Synechra ulna</i> (Nitzsch) Ehr var <i>oxyrhynchus</i> (Kitt.) Van Heurck	Fr Water, Madras	.	W West and G S West (1911-5)
<i>Synechra ulna</i> (Nitzsch) Ehr var <i>amphibyn-</i> <i>chus</i> (Ehr.) Grun	Fr Water, Madras, Trichi- nopoly, Nilgiris	.	K Biswas (1936)
<i>Synechra ulna</i> (Nitzsch) Ehr var <i>constricta</i> var nov.	Fr Water, Madras	.	.
<i>Surrella tenera</i> Gregory	Fr Water, Kodaikanal Pulneys	Peradeniya, Ceylon	.
<i>Surrella elegans</i> Ehr	Fr Water, Madras, Trichi- nopoly	.	.

*Statement showing the Distribution of the Forms Recorded in this Paper in the Indian Region—(Contd.)*

	Places of collection in S. India	Previous places of collection in India	Author
<i>Savirella ovata</i> Brebisson	Fr. Water, Nilgiris	Burma	W. West and G. S. West (1907)
<i>Tabellaria senestrata</i> (Lyngbye) Kutz	Fr. Water, Pykara, Nilgiris	Peradeniya, Ceylon	W. West and G. S. West (1901-5)
<i>Tabellaria flocculosa</i> (Roth) Kutz	Fr. Water, Kodakanal, Pulney, Masinigudi, Pykara and Nilgiris	Ceylon	W. West and G. S. Skvortzow (1930)
<i>Terpsichore nanaea</i> Ehr.	Fr. Water, Madras	Peradeniya, Ceylon	
<i>Thaumatoxylum marginatum</i> nov	Fr. Water, Madras	.	

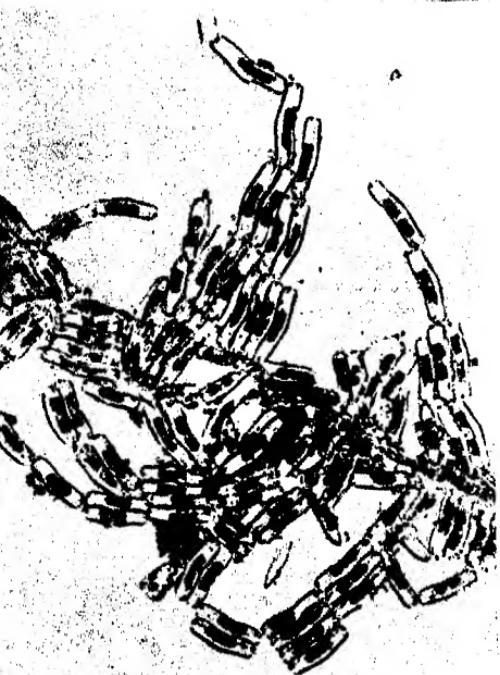


FIG. 1

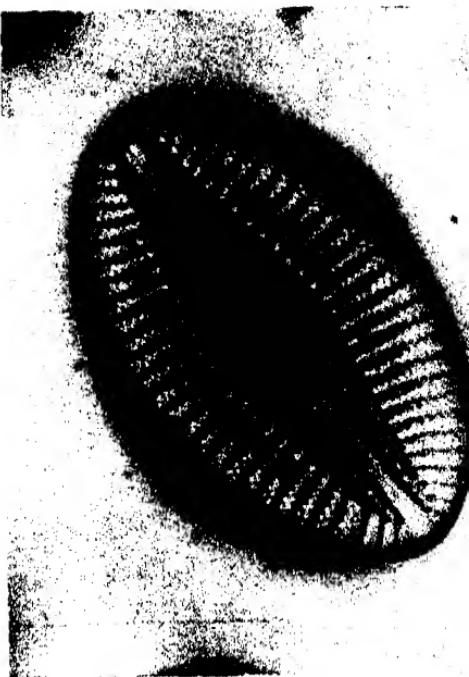


FIG. 3



## STUDY IN DISEASES OF FISH: FIN-ROT— A BACTERIAL DISEASE OF FINS OF FISH

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In November 1938 heavy mortality occurred among Gourami fingerlings (*Oosphormenus gouramy* Lacépède) when these were being transported by canal from Madras Fisheries Farm, Sunkesula to Kurnool Town—a distance of 17 miles—in a "live-car"<sup>1</sup>. The fingerlings, before despatch, had been "conditioned" for a day or two, i.e., had been confined in a "conditioning-car"<sup>2</sup>—a wooden framed box with wire netting on all sides—kept in water and starved.

In all the dead fry it was observed that the caudal fin was frayed, and observations made on the dying fingerlings, *en route* from Kurnool Town to Delhi, showed that the epidermis from the caudal fin was gradually being eaten off and the caudal rays were consequently getting exposed. In some cases the dorsal and anal fins had also been affected (Plate XVIII, Figs 1-4). The sick fry swam near the surface of the water in the container, lost their balance on the caudal fin becoming frayed upto its base, turned upside down and died, the dead ones sinking to the bottom.

The author had noticed similar symptoms among Rainbow trout fry when they were attacked by fin-rot<sup>3</sup>. In order to investigate the matter in detail, freshly dead Gourami fry were taken to the Imperial Agricultural Institute, New Delhi, and examined by the Assistant Bacteriologist. His preparation from affected caudal fin (Plate XVIII, Fig 5) showed exactly similar rod-shaped bacteria as had previously been observed by the author in Rainbow trout suffering from an attack of fin-rot.

<sup>1</sup> "Live-car" is a wooden barrel, conical at one end and round at the other, with a small opening at one side. It is made to float in water and has been in use for transport of alive fish by Madras Fisheries Department for a number of years.

<sup>2</sup> "Conditioning-car" is similar to "live-car" used in the Punjab for keeping fry under observation. Its photograph was given by the author in *Journ. Bomb. Nat. Hist. Soc.*, 1924, 29, No. 4.

<sup>3</sup> Hamid Khan, "Notes on the diseases of Trout at the Mahili Hatchery—Kulu—Punjab", *ibid.*, 1939, 60, 4, 653-56.

*Inoculation of Rainbow Trout Fry*

Some dead Gourami fingerlings were brought in water to Lyallpur and examined by the Agricultural Bacteriologist Saprophytic bacteria, in addition to pathological ones, had also made their appearance by that time To obtain pure culture of pathological bacteria, healthy Rainbow trout fry measuring from 52 mm to 66 mm in length, brought from Punjab Government Fish Farm at Madhopur, were inoculated on the 9th November 1938, at 4-30 p m with bacteria from the affected parts of the dead Gourami as follows —

- (i) The caudal fins of three healthy Rainbow trout fry were scratched with sterilized needle and rubbed with the caudal fin of the diseased Gourami fingerling, and
- (ii) three Rainbow trout fry, with scratched caudal fins, were simply placed in contaminated water in which the diseased fish had been lying

Four Rainbow trout fry with scratched caudal fins were kept as control in uncontaminated water The experiment was conducted in aquaria in Fisheries Research Laboratory at Lyallpur Temperature of water ranged from 62° F - 66° F and source of water supply was ordinary tap water Aeration of water in the aquaria was maintained by Semper's Aerating Apparatus

*Progress of the Disease*

*Rainbow Trout Fry No 1*—On the 10th November, at 8 a m , fry No 1 (Plate XIX, Fig 2) showed slightly whitish area on the free extremity of its caudal fin On the 11th, it was seen swimming near the surface of water and its caudal fin was slightly exposed at its extremity On the 12th, the rays of its caudal fin were almost totally naked and the disease had spread with great rapidity to its caudal peduncle and anal fins The caudal fin rays got disintegrated and soon after the fry lost its balance, and while it was dying its caudal fin was cut for culture of bacteria The fry died on the 12th November at 2-30 p m , i.e., after about 70 hours after inoculation and 54 hours after the symptoms of the disease became visible externally

*Rainbow Trout Fry No 2* (Plate XIX, Fig 3) —Showed external symptoms of the disease on the 11th November, at 8 a m On the 12th the fin rays of the caudal fin had become exposed and on the 13th, the caudal fin, as well as the caudal peduncle, were seriously affected The colour of the fry had become dark and it swam near the surface of the water The fry died

at 11 a m , on the 13th November, i.e., 90 hours after inoculation and 51 hours after the disease had become visible externally

*Rainbow Trout Fry No 3*—In Rainbow trout fry No 3 (Plate XIX, Fig 4), external symptoms were visible on the 12th November and the fish died early in the morning on the 14th

*Rainbow Trout Fry No 4*—Out of the second lot, in which the caudal fin had been scratched but not inoculated and the fry had been put in contaminated water, Rainbow trout fry No 4 (Plate XIX, Fig 5), showed external symptoms on the 11th November On the 12th, its caudal fin rays were slightly exposed and on the 13th it died at 11 a m

*Rainbow Trout Fry Nos 5 and 6*—Rainbow trout fry Nos 5 and 6 showed external symptoms of the disease on the 12th November and were found dying on the 14th Upper lobe of the caudal fin (Plate XIX, Figs 6 and 7), had partially disintegrated and caudal peduncle was affected upto the base of the adipose fin The infection had spread to the anal fin too Fry No 5 died on the 12th, at 12 a m , and No 6 at 3 p m , on the 14th November

Rainbow trout fry kept as control did not show any symptoms of the disease

*Rainbow Trout Fry No 7*—On the 14th November, when all inoculated fry, as well as those which had been put in contaminated water, had died, one fry from the control was transferred to the contaminated water and its caudal fin, without being scratched, was rubbed against the caudal fin of recently dead Rainbow trout fry at 12 a m On the 15th, the disease appeared on its adipose fin and the tissues at the base of this fin were seriously affected (Plate XIX, Fig 8) The fry died on the morning of the 16th November

*Rainbow Trout Fry No 8*—On the 16th November, at 9-30 a m , another fry from the control was inoculated on its caudal fin after it had been scratched, by rubbing it against the caudal fin of recently dead Rainbow trout fry On the 17th the fry showed disease at the base of the caudal fin and the caudal peduncle was seriously affected (Plate XIX, Fig 9) On the 18th attempts were made to cure the fry by putting it in copper sulphate solution (1 : 5,000), but the disease had advanced too much, caudal fin rays had disintegrated and the tissues at the base of the caudal fin had been invaded Consequently the fry died on the morning of the 19th November

The Rainbow trout fry infected with the disease, thus, died within 70-118 hours after inoculation and within 50-55 hours after the external appearance of the disease

*Table showing the Progress of Fin-rot Disease in Rainbow trout fry inoculated with the Disease from Diseased Gourami (Osphromenus gouramii Lacepedé)*

14-11-38	64° F.-66° F.							
15-11-38	64° F.-66° F.	Caudal fin rays disarranged, but rubbed against the caudal fin of recently dead Rainbow Trout Fry at 12 a.m.	—	Adipose fin and the tissues at the base of this fin seriously affected	—	At 9 a.m. incurred on its caudal fin after it had been scratched.	Attempts to cure the disease failed.	Died in the morning.
16-11-38	64° F.-66° F.	Caudal peduncle seriously affected Lost its orientation Turned up side down and died at 3 p.m. Died at 12 a.m.	—	—	—	—	—	—
17-11-38	64° F.-66° F.	Died early in the morning	—	—	—	—	—	—
18-11-38	64° F.-66° F.	—	—	—	—	—	—	—
19-11-38	62° F.-64° F.	—	—	—	—	—	—	—

\* Length is upto the base of the caudal fin, which on account of its damaged condition has not been included in the measurement

The dead fry in all the cases sank to the bottom

#### *Immunity of Indigenous Species*

Six months old fry of Rohu (*Labeo rohita H B*) and Morakha (*Cirrhina mrigala II B*), well-known indigenous food fish of the Punjab, were inoculated at the same time and in a similar manner as those of the Rainbow trout. But these fish were found to be totally immune to the disease.

#### *Etiology and Pathology*

Preparations made from Gourami (Plate XVIII, Fig 6), and from Rainbow trout fry (Plate XVIII, Fig 5), show similar rod-shaped bacteria, which are found in large numbers in the infected tissues. It is, therefore, apparent that the causative organism of the disease, both in Gourami and Rainbow trout, is the same, as it is so uniformly present in the diseased tissue. Davis (1937)<sup>4</sup> described the causative organism of fin-rot to be "a rod-shaped bacterium, which can usually be found in large numbers in the infected fins". Though no figures are given by him, it is, however obvious from the etiology and pathology of the fin-rot disease given by Davis, that the causative organism<sup>5</sup> of the disease in Gourami and Rainbow trout is the same as causes the fin-rot. The infection usually starts on the outer margin of the fin and rapidly spreads to the underlying tissues. The fins which have been injured or scratched are the first to be attacked.

Davis (1937) is of the opinion that "in small fingerlings the pectoral fins usually are affected first, the dorsal fins being attacked next, and the infection may spread eventually to the other fins, although they are rarely as badly affected". In the Gourami and the Rainbow trout fingerlings, in the present case, however, the sequence in the order of infection was different from that described by Davis. In almost all cases in the Gourami, caudal fins were affected before the dorsals and pectorals. In the Rainbow trout fry, too, the inoculated parts of the caudal fin developed the infection first.

According to Davis (1937), "In young fingerlings death usually occurs before the infection extends beyond the fins, so that the occurrence of lesions on the body is rare". The present investigations show that the disease in the case of Rainbow trout fry had spread with great rapidity to the underlying tissues at the caudal peduncle where lesions were formed before the death occurred, while in Gourami, the fingerlings died before the infection extended beyond the fins.

<sup>4</sup> Davis, H. S., "Care and Diseases of Trout," Bureau of Fisheries, U.S.A., Investigational Report, 1937, No 35, 58-60.

<sup>5</sup> Culture of causative organism on some of the commonly used Laboratory media at Lyallpur was not successful.

### *Control*

Attempts to save the diseased Rainbow trout fry, under experiment, by giving them bath of copper sulphate solution (1:5,000) for 2 minutes were not successful as the disease had spread to the underlying tissues. Control measures can only be effective in early stages of the disease before the bacteria have penetrated the tissues. Davis (1937) recommends "dipping the fish for 1 or 2 minutes in a 1-2,000 solution of copper sulphate". The copper sulphate solution of the strength recommended by Davis has been found to be too strong for young fry. It has, however, been possible to treat the diseased Rainbow trout fry successfully by putting them in copper sulphate solution of 1-20,000 strength for 10 to 15 minutes. It is impossible to cure fish in advanced stages of the disease and all such fish should be destroyed before any control measures are adopted as otherwise they will contaminate the water and form a permanent source of infection. Even healthy Rainbow trout fry, as the investigations have shown, when placed in contaminated water, develop the disease with great rapidity. It is, therefore, very essential to disinfect thoroughly all troughs, hatching and rearing trays, "live-cars" and "conditioning-cars" before putting healthy fry in them.

Rainbow trout fry have been found to suffer from the fin-rot at the hatcheries, when they are overcrowded in a live-car. It has also been found that any injury, whether mechanical or otherwise, caused by external parasite, makes the fin more susceptible to the disease. It has also been noticed that dirty, muddy rain water not only aggravates the disease, but has been found to be directly responsible for an outbreak of the disease among Rainbow trout fry. In the present case too, it seems, that transport of Gourami fingerlings by canal, where water was to some extent dirty, aggravated the disease and the fry died very rapidly.

### *Conclusion*

Fin-rot has been found to be a serious disease of Rainbow trout fingerlings at the Hatchery. The mortality is very high and it has been observed that within one week from the outbreak of the disease thousands of fry have died. The present investigations indicate that if once this disease enters a Gourami Farm, and if due precautions are not taken, it is likely to play a great havoc with the fry as well as with the adults. With due precautions it is possible to safeguard an outbreak of the disease. It is expected, therefore, that the present investigations, which have established the susceptibility of Gourami to fin-rot, will have far-reaching effect on cultivation of Gourami in inland waters in India.

### *Acknowledgments*

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### *Summary*

1 Study of fin-rot, a bacterial disease of the fins of fish, has been made by inoculation of healthy Rainbow trout fry with the disease from diseased Gourami (*Oosphromenus gouramy* Lacépède) fingerlings.

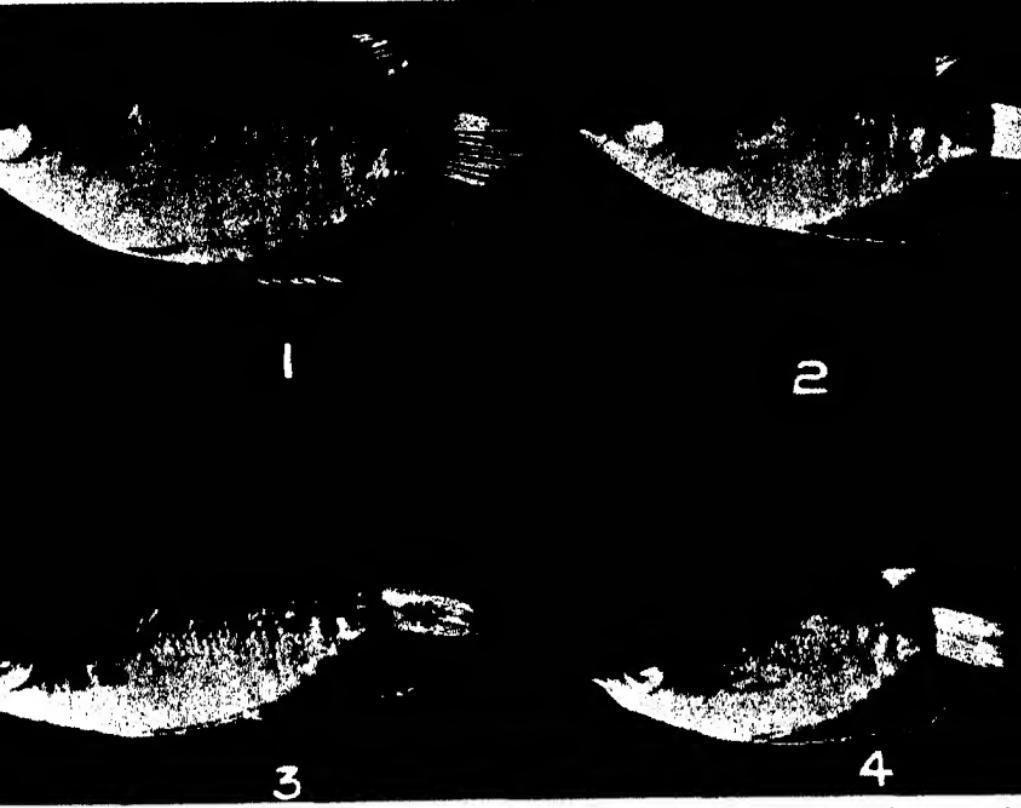
2 The Rainbow trout fry infected with the disease died within 70–118 hours after inoculation and 50 to 55 hours after the first externally visible symptoms of the disease.

3 Preparations from the diseased Gourami and infected Rainbow trout fry show exactly similar causative organism, which is a rod-shaped bacterium, present in large number in the infected tissues.

4 Overcrowding, dirty and muddy water aggravates the disease.

5 Copper sulphate solution (1–20,000) bath for 10 to 15 minutes has been found to cure the fry in early stages of the disease. It is impossible to cure fish in advanced stages of the disease, and all such fish should be destroyed before adopting any control measures.

6. Fry of indigenous fish such as Rohu (*Labeo rohita* H B) and Morakha (*Cirrhina mrigala* H B) have been found to be immune to fin-rot.



Gourami fingerlings (*Osteogaster gouramii* Lacépède), showing fin-rot on caudal, dorsal and anal fins



5

6

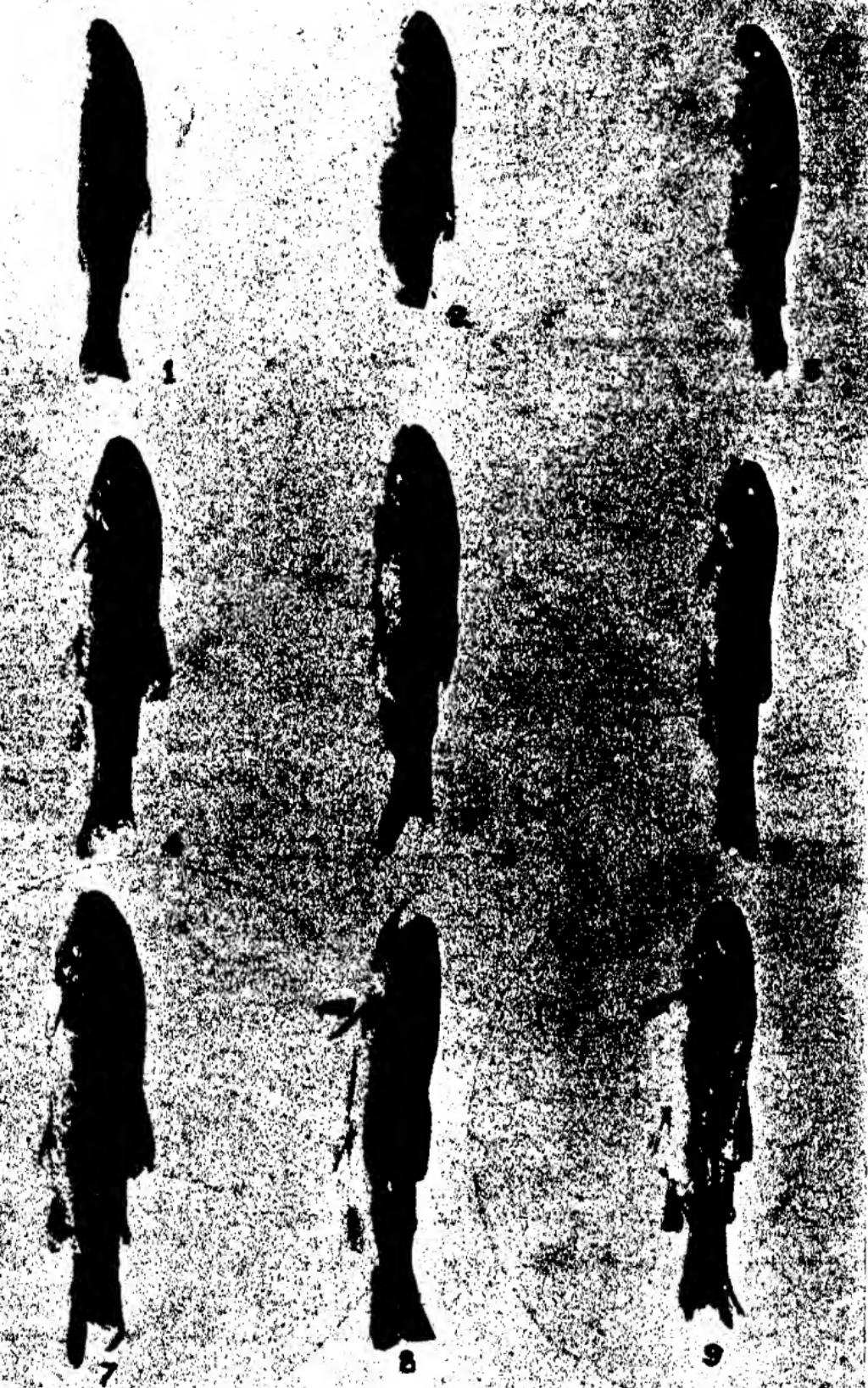


FIG. 1. Rainbow trout fry with healthy caudal fin.

FIGS. 2 to 4. Rainbow trout fry inoculated with fin-rot disease from dead Gourami fry, showing fin-rot on their caudal fins.

FIGS. 5 to 7. Rainbow trout fry showing fin-rot on their caudal fins.

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